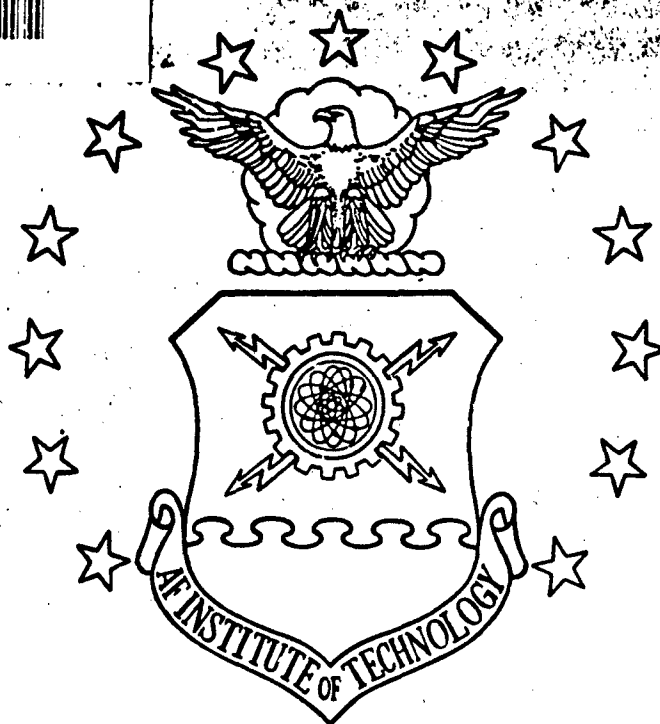


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THE INTEGRATION OF TANKER
AIRCRAFT INTO ASLAR

THESIS

John S. Stieven, Major, USAF
AFIT/GST/ENS/93M-12

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THE INTEGRATION OF TANKER AIRCRAFT INTO ASLAR

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in
Strategic and Tactical Science

John S. Stieven

Major, USAF

March 1993

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THESIS APPROVAL

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Preface

The purpose of this study was to analyze the proposed addition of heavy KC-135 tanker aircraft to the United States Air Force Aircraft Surge Launch and Recovery (ASLAR) instrument approach system. The Air Force Communications Command, which oversees ASLAR operations, will use these results to determine if KC-135 aircraft should be permitted to fly ASLAR approaches.

A SIMSCRIPT II.5 animated simulation model was developed to simulate the Runway 26 approach at Seymour Johnson Air Force Base under a variety of wind conditions. While the results from this model will be specific to this one approach, the lessons learned will apply world-wide. The work should be continued to model different aircraft and approaches.

In developing the model and writing this thesis I have had a great deal of help and encouragement from others. Col. Nordhaus, Capt. Gray, SMSgt. Nelson, and MSgt. Pratt all helped develop the assumptions that went into building the model and helped ensure the results were accurate. I am deeply indebted to my faculty advisor, Col. Schuppe, and reader, Dr. Mykytka who pushed me much farther in this effort than I would have thought possible. Finally, I wish to thank my family who have been without a father and husband for too long; Natalie, Chopper, Jessy, and Scotty, I'm finished.

John S. Stieven

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Abstract

The purpose of this study was to analyze the proposed addition of heavy KC-135 tanker aircraft to the United States Air Force Aircraft Surge Launch and Recovery (ASLAR) instrument approach system. The Air Force Communications Command, which oversees ASLAR operations, will use these results to determine if KC-135 aircraft should be permitted to fly ASLAR approaches.

A SIMSCRIPT II.5 animated simulation model was developed to simulate the Runway 26 approach at Seymour Johnson Air Force Base under a variety of wind conditions. This model was expanded to show the feasibility of KC-135s flying ASLAR approaches and to determine proper controller procedures to prevent the minimum enroute separation between aircraft from being violated. The study noted a concern with reduced separation between a KC-135 and a trailing fighter due to wake turbulence and recommended a cautious, incremental approach be applied to reducing the enroute distance.

THE INTEGRATION OF TANKER AIRCRAFT INTO ASLAR

I. Introduction

This research effort investigates the current operation of and proposed changes to the United States Air Force ASLAR (Aircraft Surge Launch and Recovery) system. It accomplishes this by computer modeling current ASLAR operation's at Seymour Johnson Air Force Base (AFB), Runway 26, for F-15E fighter aircraft along with the proposed addition of heavy KC-135 tanker aircraft. This thesis is organized into five chapters. Chapter I provides an introduction to ASLAR and describes the goals of this research. Chapter II, the literature review, looks at possible alternative solutions to ASLAR. Chapter III describes the approach to the problem this research took to accomplish the goals set forward in Chapter I. Chapter IV presents the solutions and results of the computer model runs. Chapter V gives this research's conclusions and recommendations. Finally, Appendix 1 contains a complete listing of the SIMSCRIPT computer code used in the research model.

What Is ASLAR?

ASLAR is a specific set of U.S. Air Force instrument approach procedures designed for fighter aircraft use. During inclement weather, ASLAR increases the allowable launch and

recovery rates of fighter aircraft during wartime, contingency, and surge operations by applying the following concepts:

- All aircraft fly the same ground track.
- All aircraft fly the same airspeeds and slow down at predesignated points.
- Minimum enroute separation (the distance between successive aircraft during the approach) is reduced to 1.5 miles. (Dept. Air Force, 1986:1)
- Pilots and air traffic controllers both share the responsibility for aircraft separation.
- Radio calls are reduced to only two for the entire approach, versus approximately seven for a normal approach.

The person primarily responsible for the smooth and safe operation of ASLAR is the air traffic controller. The controller is the only person who, using the radar as an aid, can monitor all aircraft on the approach; pilots flying in weather can not.

The critical input into ASLAR, which the controller carefully monitors and controls, is the Initial Approach Fix (IAF) separation between successive approaching aircraft. At the IAF, the beginning of the instrument approach, an initial separation distance of 4 to 8 miles between aircraft is required to keep aircraft from violating the 1.5 nautical mile minimum enroute separation throughout the approach. Controllers will not allow aircraft to start the instrument approach unless successive aircraft have this spacing. If there is insufficient spacing with the preceding aircraft, controllers will instruct the pilot to execute one more holding turn. If it appears the

minimum enroute separation will be violated during the approach, controllers have the option of slowing aircraft down to increase the distance between aircraft. (Dept. Air Force, 1990:2-9)

Why Is There ASLAR?

Tragedy almost struck in 1980 during a Pacific Air Forces (PACAF) COPE THUNDER exercise. In the middle of the recovery of between 40 to 50 fighter aircraft, a thunderstorm closed the primary runways at Clark Air Base (Republic of the Philippines) and its alternate, Subic Point Naval Air Station. With no other place to land, the aircraft had to hold above the airbase. Fuel starvation quickly became a real possibility since fighter aircraft only return with a 20 to 30 minute fuel reserve. When the thunderstorm abated to the point that the fighters could start to land, existing approach control procedures would have allowed the recovery of only 35 aircraft per hour. While there were a few aircraft that could continue to hold this long, most had already reached Minimum Fuel (15 minutes of fuel remaining), or Emergency Fuel (10 minutes of fuel remaining) status, and needed to land immediately! Quick thinking, and a lot of improvisation on the part of the air traffic controllers, permitted all aircraft to land safely. (Nordhaus, 1992)

The 13th Air Force Commander alerted his superiors on what had transpired and emphasized the need for new Air Force approach procedures to allow compressed landing arrival times. Shortly thereafter, the Air Force commissioned a study by the

contractors, Bryant & Associates, to identify just what these new procedures should be. (Gray, 1992)

The study done by Bryant and Associates is condensed into two Air Force Regulations and outlines ASLAR procedures. (Gray, 1992) Tactical Air Command Regulation 55-55, ASLAR Aircrew Procedures, specifies all the required actions of aircrews when flying an ASLAR approach. It covers all the new terminology associated with ASLAR. The regulation even goes so far as to determine engine throttle setting's for different portions of the approach trying to minimize the inherent fluctuations in the approach flow. (Dept. Air Force, 1986:1-8) Air Force Communications Command Regulation 60-6, the ASLAR Controller Handbook, "establishes air traffic control procedures and phraseology for use by AFCC personnel providing air traffic control services in support of the ASLAR Program." (Dept. Air Force, 1990:cover)

In 1983, this author was part of the initial cadre of aircrews to implement these procedures and be certified "ASLAR qualified" at Seymour Johnson AFB, North Carolina. Since then, ASLAR has become the Air Force standard for all fighter aircraft.

Surprisingly, even after ten years of flying ASLAR, both controllers and aircrews agree it has met with varying degrees of success. (Pratt, 1992) (Nelson, 1992) Air Combat Command (ACC) and the United States Air Forces Europe (USAFE) seemed to have had moderate to good success. On the other hand, the

Pacific Air Forces (PACAF) have had dismal results. (These evaluations are based on this author's personal experience in all three theaters of operations).

What Is Wrong With ASLAR Today?

Two recent events have highlighted the shortcomings with the current ASLAR system. The first is the recent establishment of combined Tactical Wings in the Air Force which now, for the first time on a large scale, combined heavy lift cargo and tanker aircraft with fighter units at one airport. U.S. Air Force radar approach controllers must now cope with aircraft performance characteristics that vary widely. ASLAR, as currently implemented, does not allow for the mixing of different types of aircraft in the traffic flow because of two important factors:

- Non-uniform fighter and heavy cargo or tanker aircraft penetration and landing speeds.
- Greater approach spacing (currently five miles) is required for fighter aircraft following a heavy aircraft due to wingtip wake turbulence from the heavy aircraft. (Dept. Air Force, 1990:1) (Pratt, 1992)

The second event was the Persian Gulf War in which a limited number of available airbases forced fighter, heavy airlift, and tanker aircraft to operate together from common bases. If a heavy aircraft needed to land during a mass recovery of fighters, approach controllers had two options. First, controllers could build in a large time window in the middle of the fighter approach flow, usually three to four

minutes, so that the heavy aircraft could start its approach and land. This window was necessary to provide sufficient wake turbulence separation for the fighters. This forced the fighters to hold, and as previously stated, the fighters might not have had the fuel for this option.

The second option available was to hold the heavy tanker or cargo aircraft until all the fighters had recovered, primarily because heavy aircraft usually carried a greater fuel reserve than fighters. There was one big problem with this option: a massive recovery of fighter aircraft could last upwards to 45 minutes. Delaying heavy airlift for the entire fighter recovery, given the critical shortage of airlift resupply, induced unanticipated, and unacceptable, delays in the movement of war materiel. (Gray, 1992) It became readily apparent that a better solution to this problem needed to be found in the very near future.

One possible solution postulated to overcome these shortcomings was to allow the participation of heavy aircraft in ASLAR. Air Mobility Command (AMC) and ACC officials hope that joint ASLAR operations would allow heavy aircraft to land in the middle of a fighter recovery while only minimally disrupting the approach flow. However, these procedures **currently do not exist.** (Gray, 1992)

Air Force officials have instructed Headquarters Air Force Communications Command (HQ AFCC/ATC) to determine the feasibility of joint ASLAR operations and, if feasible,

establish the standardized procedures and guidelines for them. (Gray, 1992) HQ AFCC/ATC has conducted three conferences and determined, in theory, that joint operations should be possible. In August 1992, a flying demonstration with F-15s and KC-135s at Kadena AB, Japan, tested the procedures established during these conferences. This one test modified some initial procedures yet failed to show any significant reasons that joint ASLAR operations could not be initiated. (Gray, 1992)

This one flying demonstration, however, did not give AFCC/ATC officials the confidence to unconditionally recommend joint ASLAR operations since it was conducted under one set of wind conditions and used just the final portion of the instrument approach. Therefore, HQ AFCC/ATC officials have asked for an independent analysis of proposed changes to ASLAR before they brief the Air Combat Command Deputy Director for Operations (HQ ACC/DO) in early 1993. (Nordhaus, 1992)

The purpose of this research is to provide this analysis.

What Will This Research Accomplish?

To overcome the concerns of HQ AFCC/ATC officials, this research will build a computer model to analyze an entire instrument approach under a variety of wind conditions. It will look for reasons why joint ASLAR operations should or should not be permitted. It will review the proposed flying procedures for KC-135s and recommend only needed changes. If sound joint ASLAR procedures can be found, it will establish the minimum IAF

separation distance which controllers should use to ensure its smooth operation. The output, presented in Chapter IV, will consist of six tables giving the radar approach controller:

- The minimum Initial Approach Fix (IAF) separation for the six possible combinations which KC-135 and fighter aircraft could fly an approach in trail. Each table will give this separation for a variety of winds at altitude and on the surface.
- The average expected separation distance aircraft crossing the runway threshold will have with the trailing approach aircraft or element.
- The expected percentage of aircraft that would be required to slow down due to insufficient in-flight separation.

From these tables, officials can determine the ASLAR expected landing rate for a particular scenario of fighter and heavy aircraft.

The research will also compare the simulation model's results with the Bryant and Associates stated ASLAR arrival capacity of 80 aircraft an hour. This is of interest because a possible reason for the varying degrees of success with ASLAR may be an overstated expectation of arrival capacity.

How Will This Be Accomplished?

A SIMSCRIPT simulation model will first model the current ASLAR instrument approach, Runway 26, at Seymour Johnson AFB, North Carolina (see Figure 1 next page). This will establish a base line for ASLAR approach capacity.

91346
(ASLAR) HI-TACAN 2
or ILS RWY 26

A-226
 ALR-169.03 (USAF)

SEYMOUR JOHNSON AFB (KGSB)
 GOLDSBORO, NORTH CAROLINA

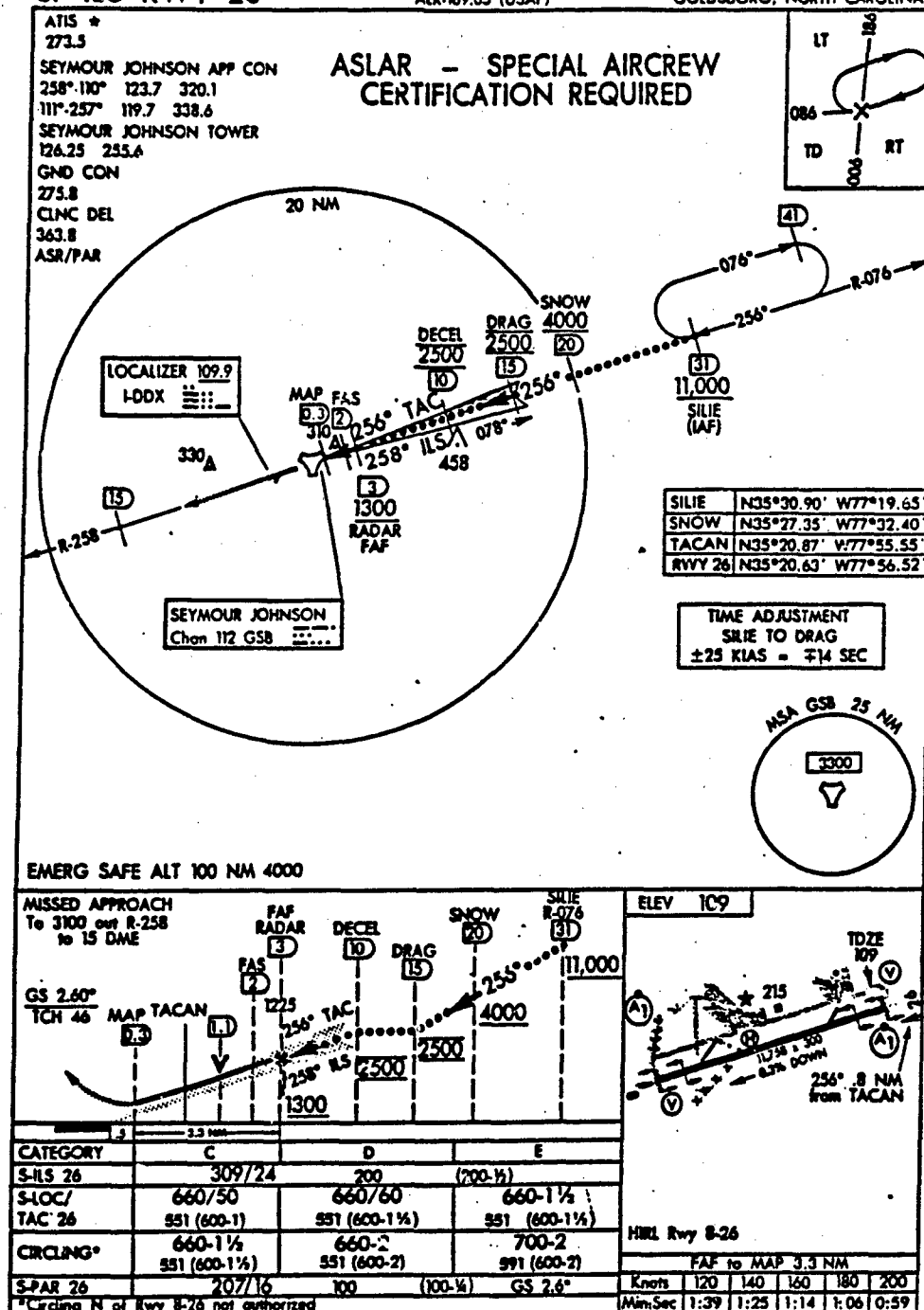


Figure 1

Why choose this specific approach? First, it is the primary instrument runway into Seymour Johnson AFB and an approach I have flown for a total of five years. Second, the F-15Es currently flying there have similar flying characteristics to the F-15Cs flown during the Kadena AB flying demonstration. These flying attributes were used as inputs to the simulation model. Third, Seymour Johnson's chief of Air Traffic Control (ATC) provided established procedures and "rules-of thumb" used in everyday operations. This greatly simplified the effort required to validate the simulation model's output, assumptions, and coding by allowing direct comparison of the real world with the "reality" presented in the model world. (Nelson, 1992)

Once a basic model of the Seymour Johnson AFB instrument approach is built and validated, it will be expanded to model KC-135 tanker aircraft. Analysis of the simulation's output will either confirm HQ AFCC/ATC proposals, or show why they might be unacceptable. It will also provide a realistic estimate of a proposed system's performance.

Why Use A Simulation Model?

A simulation model was chosen to solve this problem for the following reasons:

- There is random behavior exhibited by aircraft during the instrument approach.
- The model uses information about successive aircraft to affect the behavior of all aircraft.

- The model explores complex policies in a fraction of the time and cost that actual flying would require.

- The simulation language chosen has the capability to "animate" the model.

The last point is important because the intended audience for this effort will not be other analysts, but policy makers and approach controllers.

The animated model provides a communication tool not available with any other technique. The model's animation looks like the approach radar screen in the tower. By observing the model in action, officials and controllers alike can see the consequences of their choices without having to sift through reams of computer printouts; they can use their years of experience to guide them. It will either confirm their initial suspicions or, if the model shows some counter-intuitive solutions, see why their initial feelings were in error.

What Won't The Thesis Do?

Air Combat Command and Air Mobility Command officials have already decided there will be no change in ASLAR for fighter aircraft. Therefore, no changes are even explored. They also decided only one type of heavy aircraft (KC-135's) would initially fly ASLAR approaches; however, they leave open the possibility of additional heavy aircraft participation at some later, undetermined date. Therefore, only the flying characteristics of the KC-135 are modeled.

They also determined KC-135s will fly the initial approach at 300 KCAS (Knots Calibrated Air Speed), slow down to 180 KCAS

at the published DRAG point, and slow to 140 KCAS at the final approach speed (FAS) point. They decided that existing wake-turbulence spacing was excessive and unrealistic and established new separation criteria of:

- Airborne aircraft will come no closer than 1.5 miles to another, anytime.
- A fighter can not land behind a tanker unless the tanker aircraft is 8000 feet down the runway.
- A KC-135 can not land behind a fighter unless the fighter is 8000 feet down the runway.
- The minimum runway separation between fighter aircraft is 3000 feet, approximately 1/2 mile.
- The minimum runway separation between KC-135s is 8000 feet.

With all these factors predetermined, this thesis will not determine if these changes should be made, that is the responsibility of the decision maker. It will only depict the results if, and when, these changes are made. Follow-on research may use the findings from this thesis if additional heavy aircraft are ever allowed to participate in ASLAR.

Terminology

The following aviation terms provide readers with a basic understanding of ASLAR terminology:

- Nautical Mile. A measure of distance that is 6076 feet long. This is different from a statute mile which is 5280 feet long. All distances referenced in this research are in nautical miles.
- Knot. A measure of speed expressed in nautical miles per hour. All speeds referenced in this research are in knots.

- Knots Indicated Airspeed (KIAS). The speed a pilot reads off his airspeed indicator.

- Knots Calibrated Airspeed (KCAS). KIAS corrected for any instrument installation error. At the airspeeds consistent with ASLAR approaches, KIAS is approximately equivalent to KCAS. ASLAR approaches have specified speeds, given in KCAS, which all aircraft must fly.

- Knots True Air Speed (KTAS). The speed an aircraft flies through the air. For a given KCAS a pilot is flying, the aircraft's KTAS will usually be greater. For example at the start of the ASLAR approach, the pilot flies 300 KCAS which equates to about 360 KTAS. While most aircraft also have a KTAS readout, KCAS is used for instrument procedures.

- Ground Speed (GS). The speed an aircraft appears to be moving compared to an observer on the ground. This is the speed aircraft appear to be moving to the radar approach controller. Ground Speed is greater than KTAS when an aircraft is experiencing a tail wind and less than KTAS when an aircraft is experiencing a head wind.

- Radial Distance. The distance an aircraft is from the approach control radar. The model assumes the radar is at the far end of the runway, not the approach end. Radial distance is horizontal distance corrected for an aircraft's altitude.

- Fighter Element. Two fighter aircraft consisting of a leader and a wingman.

This is the only independent study conducted on ASLAR since 1981, and while the results from this effort will be specific to this one approach at Seymour Johnson, the concepts and procedures developed should apply worldwide as most instrument approaches have at least a 10-mile, straight-in final. (Gray, 1992)

II. LITERATURE REVIEW

Airport Operations (Today):

Lacking the practical experiences of mixing flying operations of many different aircraft types, it seems reasonable for Air Force officials to look to the civilian airline industry to help solve its problem. The Air Traffic Control (ATC) system in the United States routinely handles the mixing of aircraft as small as business jets to as large as Boeing 747's. Like the Air Force, the primary concern of airport administrators at the nations busiest airports are to land safely the most aircraft in the minimum time.

In the past, the preferred way to expand an airport's landing capacity was to add a new runway or lengthen an existing one (allowing larger aircraft types to land). Another option was to build an entirely new airport. Neither of these options are currently available to Air Force officials leaving them with only one option: enhance the operations of existing airports.

The Air Force, in concert with the Federal Aviation Administration (FAA), has upgraded air traffic control radars and approach landing systems which allow aircraft to continue operations with ceilings as low as 100 feet and visibilities of only 1/4 mile; military cargo and tanker aircraft routinely fly to these approach minimums. (Loftus, 1992) However, under normal conditions, all fighter operations are suspended when the

cloud ceiling is less than 300 feet and the visibility is less than one mile.

To aid controllers in the efficient and safe recovery of arriving aircraft, aircraft must report to ATC when they overfly designated checkpoints, called Initial Approach Fixes (IAFs), normally about thirty miles from the airport. At busy civilian airports, there can be up to four IAFs allowing arrivals from all directions; these fixes then funnel aircraft into the approach sequence.

Controllers specify the time which an aircraft is supposed to be at the IAF. The determination of this time is the responsibility of the approach controller and is made using his or her experience. Once an aircraft is past the IAF, the civilian controller constantly directs heading and airspeed changes until the aircraft lands. This process, thus, is very labor intensive. (Pratt, 1992)

ASLAR, on the other hand, simplifies an aircraft's approach. Normally, there is only one IAF. Local regulations at most military airbases direct aircrews to attain a specified enroute spacing with the aircraft in front of them prior to the IAF when ASLAR is in effect. Aircrews have no knowledge of who ~~else~~ might be going to the fix, only if the person in front of them is going there also. These regulations offer some congestion relief to military controllers who can not talk to, nor control, the inbound aircraft until the civilian FAA system relinquishes control. This normally occurs about 10 miles from

the IAF. By that time, there is little the controllers can do to change whatever spacing aircrews have established. The predictable result is that airplanes start to stack up at the IAF wasting precious fuel.

In a contingency scenario, such as Desert Storm, the military controls the entire airspace. Controllers are then able to affect control of inbound aircraft much farther away thereby reducing congestion and terminal delays. (Gray, 1992)

While military controllers also designate the time for aircraft to leave the IAF, once a fighter aircraft leaves the IAF at the specified in-trail distance, military controllers usually only monitor the aircraft's progress. This hands-off type of approach is possible since there are published, strict guidelines on how each approach is to be flown. Additionally, aircrews can not participate in ASLAR unless they are certified "ASLAR Qualified" by an instructor. Therefore, unless a dangerous situation develops, controllers do not intervene in the aircraft's approach, resulting in reduced controller workload but, perhaps, less than optimum arrival scheduling. (Gray, 1992)

AIRPORT OPERATIONS (FUTURE):

No matter how sophisticated the approach radar or landing system, errors will be introduced into airport operations because humans direct and fly the aircraft. This reduces the overall efficiency and translates directly into enroute delays

and a reduction in the operating profits of the nation's airlines. FAA and airline officials, therefore, are constantly searching for the best way to reduce system errors. There are no current or future systems designed to take the pilot out of the cockpit; therefore, officials are concentrating their studies on air traffic control. Proposed computerized "expert systems" will help controllers obtain and implement the optimum schedule for landing aircraft.

Credeur (Credeur and Capron, 1989) introduces the concept of TIMER, Traffic Intelligence for the Management for Efficient Runway scheduling. TIMER uses a 4-Dimensional (x, y, z, and time) model to integrate enroute traffic flow, fuel-efficient cruise and profile descents, terminal area time-based sequencing and spacing, and computer-generated controller aids to provide optimum use of runway capacity. Its key to increasing airport capacity is starting the scheduling process while airplanes are still some distance away from the airport. This reduces the current runway interarrival error (planned arrival time versus actual time) from about 26 seconds to between 8 and 12 seconds.

Lin (Lin and Liu, 1991:111-117) proposes a man and machine intelligence system to provide a knowledge-based, EnRoute Monitor System (ERMS). This system offers aircraft separation aids to the controller during the cruise phase of flight until the aircraft enters the terminal control region (TCR). Once there, the Air Terminal Control Monitor (ATCM) guides aircraft all the way to landing. These systems receive information from

the airplane, weather reports, and the airport's radar system. Combining this information, the ERMS/ATCM interface schedules the optimum sequence for landing aircraft.

Fricke (Fricke and Horman, 1990:39-1,16) introduces a system called TASIMD (Terminal Area SIMulation considering the aircraft Dynamics). TASIMD models all the air traffic control elements for automated approach procedures. By considering random influences (entry fix time deviation, navigation errors, wind, and airspeed errors) on the desired flight path, TASIMD immediately notifies the controller of any deviations from the model's plan. This increases the controller's knowledge of an aircraft's flight path and position allowing for a reduction in the aircraft position safety buffer by 20 seconds or more.

Davis (Davis and others, 1991:848-854) evaluates the Final Approach Spacing Tool (FAST) which assists terminal radar approach controllers in sequencing and spacing traffic onto the final approach course. FAST display's speed and heading advisories to arriving aircraft as well as sequencing information on the controller's radar display. Evaluated by a group of experienced air traffic controllers in a real-time simulation, FAST significantly reduced controller work load and reduced aircraft interarrival time.

Budd (Budd, 1989) introduces a method for allocating aircraft landing times using the "Time Horizon." It evenly distributes enroute delays among all aircraft by allocating a landing time slot when an aircraft is a fixed time (not

distance) away from the airport; the "Time Horizon." This reduces the gaps in arrivals effectively increasing runway capacity.

Most of these new systems strive to start controlling or, at least, receiving information about incoming aircraft while they are still some distance away from the airport. The intent is to keep aircraft from stacking up at the IAF's.

Yet while each of these new systems has shown potential to increase the number of landing aircraft, some by as much as 23%, they are not without their problems. The Air Force can not afford the large expenditures in training and equipment these systems would require given the realities of today's military budget. There is also the issue of when these systems can **really** become operational.

Therefore, while "state of the art" systems may well help solve the Air Force's problem of controlling aircraft with a variety of flying characteristics in the future, Air Force officials feel they can not wait until the international aviation community decides which, if any, system will become the standard and then implement it. Officials want a solution to their problem **today**. (Nordhaus, 1992)

III. APPROACH TO THE PROBLEM

Methodology

This research chose the following building block approach to analyze the proposed changes to ASLAR. First, as summarized in the previous chapter, the current literature was reviewed to discover what new approaches the airline industry was taking to solve similar problems and to determine the validity of using these to help the Air Force.

Second, a group of ASLAR experts were gathered and consulted. These experts provided guidance in two very important areas. They all agreed that, even though ASLAR is used for both the launch and recovery of aircraft, the focus of this effort needed to concentrate on the landing portion. They also helped determine the assumptions and variables that needed to be modeled in order to obtain a realistic portrayal of ASLAR.

Third, with the proper focus and assumptions in hand, a flow diagram for the base computer model was constructed to aid in the development of the computer code. It turned out that, with only slight modification, this flow diagram was also used for the expanded model.

Fourth, a base simulation model of ASLAR was constructed using current, Runway 26, procedures. It was decided to add the animation capability of the model from the very beginning as opposed to waiting until a complete working model was complete. The erratic behavior of the animated radar returns caused a

change in the formulation of the computer model; the decision was made to switch from a continuous change to a discrete change simulation. The animation also helped in the initial verification of the model logic by "showing" errors versus analyzing model trace outputs.

Fifth, the experts were consulted once again to help validate the base model and analyze its results. A determination was made that the model provided an accurate representation of the current system.

Sixth, with confidence gathered from the base model, the proposed changes were coded into an expanded model. The expanded model explored all six in-trail approach combinations for fighter and KC-135 aircraft.

Seventh, by systematically changing the model's inputs, the desired results -- minimum IAF separation distance, the average distance between aircraft at landing, and the percent of aircraft requiring controller intervention -- were recorded. Eighth, the results were analyzed to determine the feasibility of joint ASLAR operations and to obtain a truer estimate of ASLAR's maximum arrival rate. The results from the expanded model are presented in Chapter IV. AFCC officials have decided to include these results into the briefing that will be given to the ACC/DO in March, 1993.

The Expert Group

A number of experts helped clarify, quantify, and then validate the assumptions that went into the SIMSCRIPT model. Each of these experts brought unique experiences and insight to this research. The experts were:

Colonel Nordhaus, Scott AFB, IL
Major Stieven, Wright Patterson AFB, OH
Captain Gray, Scott AFB, IL
Senior Master Sergeant Nelson, Seymour Johnson AFB, NC
Master Sergeant Pratt, Wright Patterson AFB, OH

Gray is a radar approach controller and is responsible for drafting the new ASLAR procedures for HQ AFCC. He chaired all recent meetings on the changes to ASLAR and participated in the flying demonstration at Kadena AB. Nordhaus (called the godfather of ASLAR by Gray) chaired the initial steering committee overseeing the implementation of ASLAR in 1981 and has been active in refining ASLAR ever since. Nelson is the senior approach controller at Seymour Johnson AFB and has implemented ASLAR there from its inception. Pratt is the senior approach controller at Wright Patterson AFB and has controlled ASLAR approaches since 1983. Finally, I used my personal experience from observing ASLAR from the flying perspective for 10 years and also from monitoring controller (and aircrew) procedures as a Supervisor of Flying (SOF) during mass recoveries of aircraft.

The Variability in the Landing Portion Of ASLAR

The experts knew the key to making ASLAR work was establishing efficient procedures for the approach and landing

portion. What was it that made the landing portion different from the takeoff portion of ASLAR? The primary difference is that there is really very little **variability** in the mass launch of fighters during a contingency. The person responsible for the launch, the Mission Commander, determines the takeoff time for all aircraft usually one day in advance. He briefs all parties, including Air Traffic Control (ATC), on what those times will be, how long it will take to launch all the airplanes, and how there will be **no acceptable reasons** for delaying, or interrupting, the takeoff once started. With this information in hand, controllers simply notify airborne aircraft to either land in advance of the mass launch or hold for the anticipated delay.

The landing portion, however, is much more variable. Just because there is a mass launch of aircraft from a single airport does not mean they will all come back at the same time. The aircraft may have separate missions and airborne refueling options. Airplanes may divert from an intended landing base because of weather or enemy damage. Additionally, just when will the "scheduled" airlift really arrive and will this be in the middle of a fighter recovery?

Probably the most important reason to concentrate this effort on the landing portion of ASLAR is that the efficient control of returning aircraft, with possibly limited fuel reserves, takes precedence over aircraft taking off. Running

out of fuel on the ground has markedly different consequences than running out of fuel while airborne.

Add all these reasons together, plus the pressure approach controllers continuously work under, and it is easy to see how the best laid plans can fall by the wayside. It shows how important a well thought out, simple, workable plan is to the safe recovery of aircraft. For controllers, nothing can be simpler than ASLAR. (Gray, 1992)

After holding numerous discussions with this group of experts, the next step was to make use of their collective knowledge and formulate the assumptions that would form the foundation for the simulation's base model. This was important because, as stated by Pritsker, (Pritsker, 1986:4) a model is only "...an abstraction of a system. To develop an abstraction, a model builder must first decide on the elements of the system to include in the model."

The Model Assumptions

By carefully choosing the following assumptions, this research effort tried to accurately, yet efficiently, depict the Runway 26 instrument approach at Seymour Johnson AFB. (See Figure 1 in Chapter I)

- An aircraft's position at the start of the approach, abeam the IAF, is between 2 mile's left and right of course. This takes into account aircraft position error. The error is assumed to decrease steadily as the approach is flown and finally becomes zero when the aircraft reaches the "2 mile final" point.

- Aircraft depart the IAF in whole number separation distances; e.g., 6 or 7 miles apart versus 6.4 miles apart. This corresponds to the accuracy of the approach controller's scope. IAF separation distances in the model were reduced until, at most, 5% of the aircraft were required to slow down due to violating the minimum 1.5 mile enroute separation.

- Aircraft airspeed departing the IAF is between 295 and 310 KCAS.

- Aircraft headings do not deviate more than 5 degrees in a direction that takes the aircraft further away from the course centerline. There is no such restriction on a heading taking the aircraft to course centerline.

- Aircraft KCAS airspeed during the approach varies within $\pm 10/-5$ knots of the specified speed. This tolerance would be acceptable on an evaluation by a flight examiner.

- Aircraft Knots True Air Speed is computed for International Civil Aeronautics Organization (ICAO) standard day conditions: 59°F at Sea Level with a corresponding temperature drop with increasing altitude, and a barometric pressure of 29.92.

- Aircraft dive angle varies between 5.25 and 6.5 degrees during the initial portion of the approach. This equates to a vertical velocity tolerance between 3000 and 4000 feet/minute.

- Winds are constant. Wind shears, a sudden increase or decrease in wind velocity, if they occur, happen at 4000 feet. Surface wind values varied from 10 knots tailwind to 20 knots headwind. In the model, winds at altitude varied from 30 knots tail wind to 60 knots headwind.

- Aircraft Groundspeed (GS) is computed using the variation in dive angle, position error, heading, airspeed, and wind..

- An aircraft initiates all appropriate maneuvers at the designated points. When an aircraft decelerates at the DRAG, DECEL, or FAS points on the approach, (see Figure 1) it first slows down to the specified airspeed and then airspeed varies between $\pm 10/-5$ knots.

- Two fighters flying in formation attain at least a 1.5 mile separation by having the wingman slow to 180 KCAS at the DRAG point while the leader continues at 300 KCAS for five more miles before slowing down to 180 KCAS at the

DECEL point (see Figure 1). From the time an aircraft starts to slowdown until it is established at 180 KCAS takes no more than 2 miles.

- Aircraft position is recomputed in 1-second time intervals.
- A fighter's approach speed is between 160 and 175 KCAS.
- A tanker's approach speed is between 135 and 150 KCAS.
- A tanker requires between 38 and 42 seconds to go 8000 feet during landing rollout.
- A fighter requires between 45 and 49 seconds to go 8000 feet during landing rollout.
- Controllers only slow down aircraft within 8 miles of the airport. Once an aircraft receives instructions to slow down, its speed variation reduces by 50%. This simulates the increased diligence aircrews will take to keep from having to repeat the approach due to their own error.

Now that the assumptions had been agreed upon and the focus determined, the next step was to build a flow diagram, or a logic diagram, for the base model.

The SIMSCRIPT Model Flow

There are nine subroutines, or processes, in the SIMSCRIPT simulation model. Of these nine, only one is really important for the reader to understand; the FTR process. This process is the major subroutine which combines all the modeling assumptions for ASLAR with some of the logic required for the animation.

The only other significant process, FTR2, mirrors the FTR process with the exception there is no logic for heavy aircraft. This routine is only called when a fighter drags its wingman, which in all cases is another fighter. The other processes define variables, set initial values, and set up the animation.

The flow diagram in Figure 2 (see next page) depicts the logic used to build the FTR process. The "R" defined in the flow diagram is an aircraft's radial distance from the approach control radar. With the flow diagram acting as a guide, the actual coding of the base model began in earnest.

Building The Base Model

The base model was built in a two-step process. The first model built was for a single aircraft on the approach. There was no controller interaction, no interaction with other aircraft, and no wind. This model was built really just to test the animation capability of the model and discover any logic errors that might exist.

As previously discussed, the decision to write the base model in the SIMSCRIPT II.5 programming language was determined in large part because of the ease in which the model could be animated. The animation would play a larger part in the development of the model than first anticipated.

The base model started out as a continuous change simulation where all variables were recomputed in very small time steps; somewhere on the order of once every 1/100 of a second. The model, therefore, continuously computed the radial distance for aircraft on the approach in approximately six foot increments. It was thought a continuous simulation was required because the distance between aircraft needed to be constantly computed to see if, and when, the 1.5 mile minimum enroute

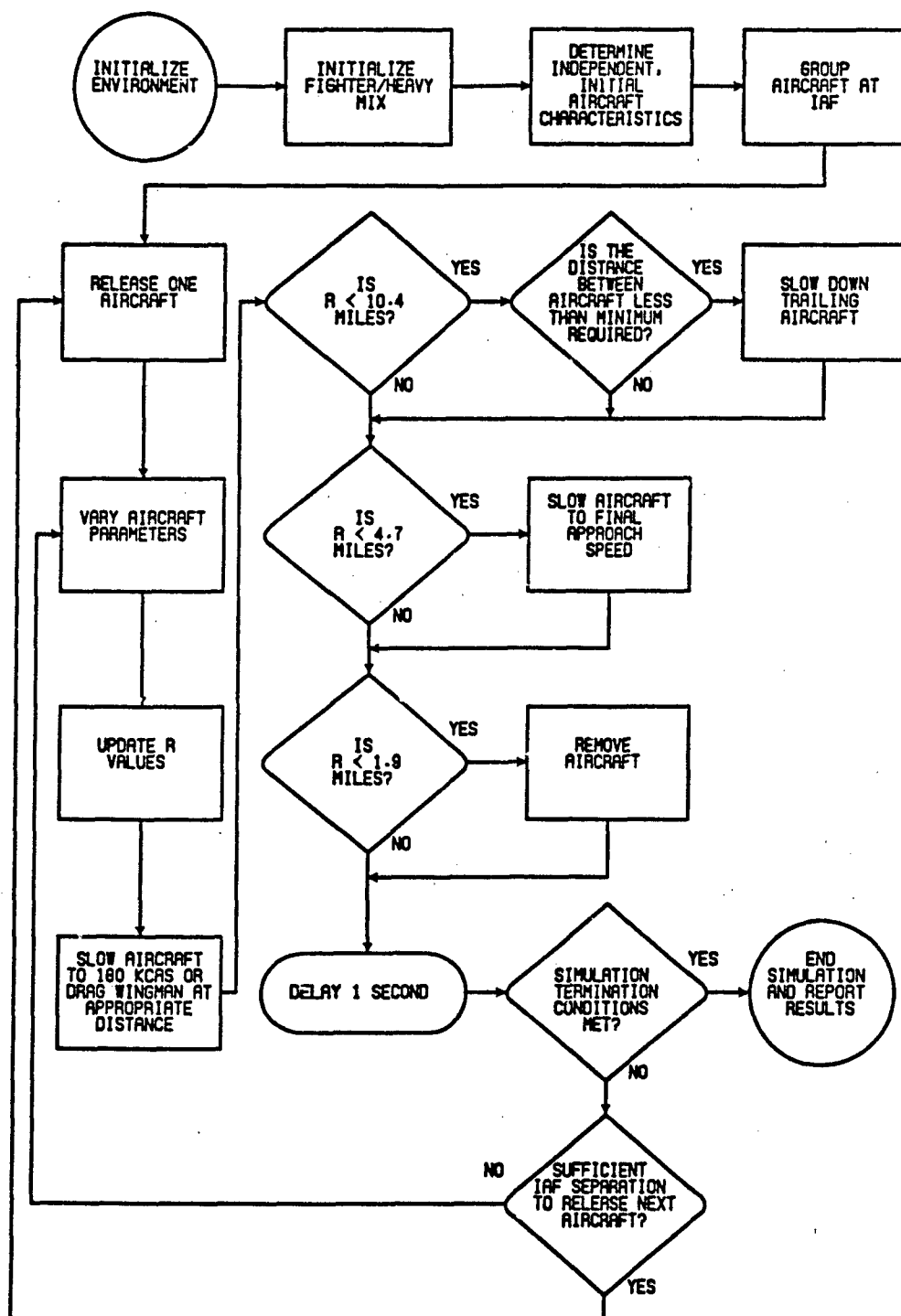


Figure 2, Flow Diagram For FTR Process

separation might be violated. While the actual coding of the model presented very little problems, when the animation was added, it became obvious a different approach needed to be taken.

The problem with the animation was that the animated radar blip representing arriving aircraft moved smoothly only until the simulation reached a logical decision point where something new needed to happen, such as the airspeed reduction at the DRAG point on the approach. This is called crossing a threshold.

SIMSCRIPT defines a certain tolerance of the threshold in which the value of the aircraft's radial distance must be computed in order for the computer to recognize that the decision point has been crossed. This tolerance was .0001 miles for this model, or .528 feet. Since the model was stepping along in six foot increments, rarely did the newly computed distance fall within this much smaller range. What then happens if there is a crossing of the threshold value outside the allowable tolerance is that the computer program backs up, reduces the step size, and tries once again to compute a value within the tolerance. This keeps happening until the computed values falls within the tolerance. Unfortunately, all this computation was not internal but was shown in the animation; the radar blips would actually back up and oscilate back and forth around the threshold value and then, finally, continue down range. The chances of convincing anyone that the model was

accurate with this kind of animated movement was zero and a different approach was required.

The decision thus was made to go instead to a discrete change simulation using 1-second time increments. This increment was chosen as a compromise between model speed and the desired accuracy of the model's variables. When this change was made, the animation moved smoothly down the entire range of the radar display.

Now that the problem with the animation had been solved, the second base model could be built. It added a wingman that would DRAG at the appropriate point in the approach, wind, and also controller interaction. This interaction would simulate the controllers ability to slow aircraft down during the approach. Since ASLAR is primarily flown by elements of fighters, this model had to work correctly before any analysis, or building an expanded model, could begin.

The Animation

Figure 3 (next page) depicts the animation used by the model. The figure on the right is the representation of the approach controller's radar screen. This radar gives controllers an overall picture of how the approach is proceeding. Approaching aircraft, or radar blips, can be seen on the screen as dots.

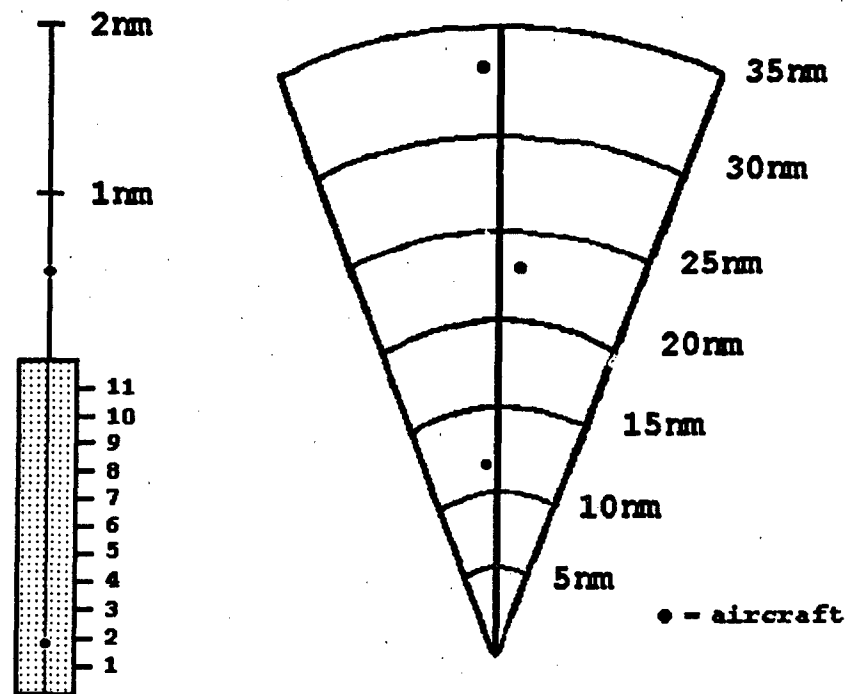


Figure 3, Animation

As aircraft get closer to the airbase, the approach controller hands off responsibility for the aircraft to the final controller. The final controller uses a different radar scope which has an expanded range scale to more easily see the distance between aircraft. This is represented by the figure on the left. The airbase, (the shaded bar) however, does not show up on either radar screen. The airbase was only added to the left figure to show how changing the IAF separation translates to changing runway separation distances.

If the animation is supposed to be an accurate representation of the real world, why don't Figures 1 and 3

look exactly alike? Why are there differences in the orientation between figures? The animation is supposed to be an accurate representation of the approach controller's radar screen, not the approach. Therefore, there will be some differences.

It should be noted that distances on the radar screen do not correspond with distances on the approach. The reason is because the controller sees radial distance on the radar, measured from the far end of the runway, and the pilot receives distance from a specific navigation aid, in this case it is called a TACAN. At Seymour Johnson AFB, the TACAN is not collocated with the runway but .8 miles short of the runway. When pilots report "10 mile final" to the controller, the pilot is reading this distance off of the TACAN. The controller would actually see the aircraft at approximately 13 miles on the radar; the aircraft is 10.8 miles from the approach end of the runway, the runway is 1.935 miles long, plus the airplane is at some altitude.

While the orientation of the controller's radar scope is chosen for convenience, the orientation of the approach depiction is one of necessity. In the control tower, the radar screen has an extended runway centerline which in our case extends to 35 miles. The parameters which interest the controller are how far an aircraft is from the runway and how far it is to the left or right of the centerline course. If an aircraft is left of course, the controller simply directs the

aircraft to turn right to get back to course. The controller's radar scope display does not rotate if the approach is flown to the other end of the runway, only the radar changes direction.

For the pilot, the orientation of the approach is very important. The approach depiction gives an overhead view of the entire approach to build situation awareness about where towers might be, where towns are located in relationship to the airbase, in effect, anything a pilot might use to find the airbase if the visibility or weather gets bad. Therefore, the approach must be oriented in the proper direction.

Once the model had been built and debugged for syntax errors, the hard work lay in figuring out if there were any logic errors. The only way to do this was to observe the animation and analyze the results put forth by the base model. The methodology used to obtain the base model's results was the same as used in obtaining the expanded model's results. This methodology will be explained later in this chapter in the discussion on obtaining the results from the model.

The actual computer code of the base model is not presented here since it was used as the foundation of the expanded model and, except for the addition of variables for the KC-135, was identical to the expanded model. A line by line analysis of the model logic is included later on in this chapter in the discussion on the expanded model.

Analysis and Validation of the Base Model's Results

The results from this base model were obtained by sending sets of between 200 and 1000 aircraft through the simulation model with 250 being the median value. Two critical items which had to be correct were the model's estimate of the mean distance between the wingman and his leader and, secondly, the minimum distance between elements of fighters departing the IAF. If these numbers were unrealistic, the other data from the model would also be worthless.

What numbers would be acceptable for these values? The experts had agreed that the expected value for the distance between a wingman and his leader was somewhere around 1.75 miles and Nelson used a minimum eight mile IAF separation between elements in the everyday operation of ASLAR at Seymour Johnson AFB. Since this model was trying to accurately depict a working, functioning system, these values were accepted as correct.

Initial results from the base model computed the distance between the wingman and his leader as averaging 1.79 miles in-trail (see Figure 4 next page). The values given at the top of the histogram are the computed minimum distance between a wingman and his leader, the maximum distance, the mean distance, the variation in these values and their standard deviation. The model also showed that, in order to keep the proportion of aircraft being forced to slow down due to violating the minimum enroute separation to less than 5%, successive elements of

$\min(y) = 1.485$ $\max(y) = 2.194$ $\text{mean}(y) = 1.791$
 $\text{truevar} = 0.022$ $\text{stddev} = 0.15$

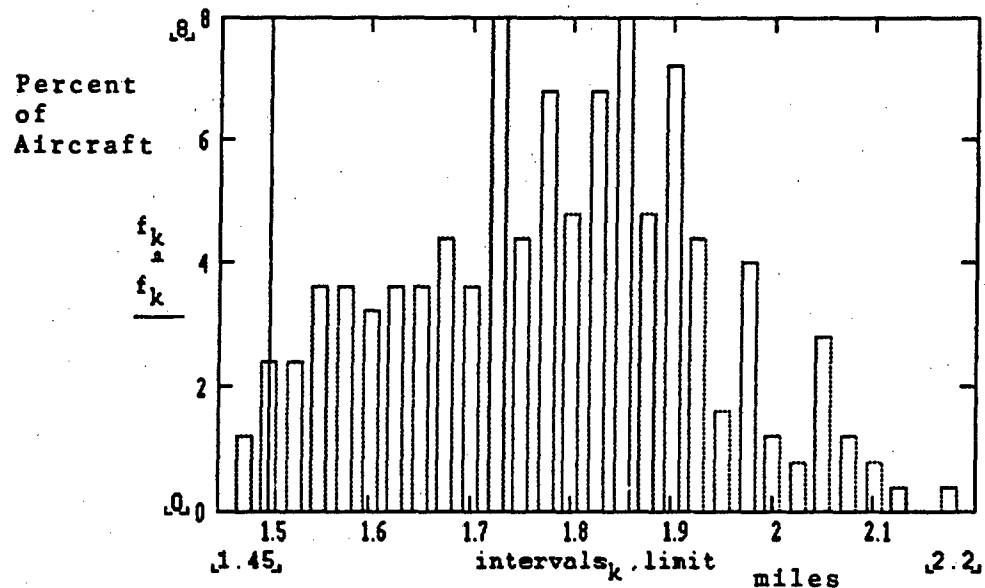


Figure 4, Distance Between Leader and Wingman

fighters would indeed require a minimum IAF separation of eight miles.

These initial findings confirmed that the model, even though it did not model every possible variable, had successfully modeled those **important** variables close enough to their actual values to give accurate results.

With reasonable results achieved with elements of fighters going through the model system, model runs were then completed for all possible trailing combinations of a single fighter and fighter elements. This would more accurately depict the current ASLAR system and give another opportunity to expose any logic

errors in the model's computer code. These runs were completed for the entire range of modeled wind conditions. Consistent results were achieved throughout this more strenuous testing of the model and no additional errors were found. The results from these runs are found in the next chapter.

After conferring with other experts, and showing the results obtained by the base model, the decision was made to start building an expanded model with the addition of the KC-135 tanker aircraft. The base model showed that it had accurately depicted the existing ASLAR system at Seymour Johnson AFB.

Building The Expanded Model

While there had been a wealth of expert knowledge about fighters and ASLAR, there was no such data available for KC-135 operations. The flying attributes modeled into the expanded model are a combination of data from the flying demonstration at Kadena AB and bits of information gathered from the expert group. Since no additional flying demonstrations are currently planned, current KC-135 flying procedures and approach airspeeds are different from what is being proposed for their inclusion in ASLAR, and Nordhaus and Gray were comfortable with the data and assumptions, this research assumed the limited data was representative of nominal conditions.

There were some differences from the base model that had to be resolved while building the expanded model to accurately code the model logic. In the base case the enroute 1.5 mile

minimum spacing, versus the 3000 foot minimum runway spacing, always proved to be the constraint limiting the number of landing aircraft during any allotted time because we were dealing with only one type of aircraft. Therefore, all we had to do was monitor the enroute separation and we knew that runway spacing would not be a factor.

Would this constraint also hold true for the expanded model where a new type of aircraft was added? Might the 8000 foot runway separation restriction, and not the 1.5 mile minimum enroute separation, become a system constraint? Could the constraint change depending on what type of aircraft followed the other? If the model's logic and code did not accurately reflect which constraint was acting on the system for all possible trailing combinations of tankers and fighters, an incorrect assessment of the system's true capacity would have been obtained.

There were three new cases to be solved; one where the heavy KC-135 followed the fighter, one where the fighter followed the KC-135, and one where a KC-135 followed another KC-135.

Case 1: Heavy KC-135 following a fighter. It takes the KC-135 38 seconds to go 1.5 miles at 140 KCAS. This amount of time would not allow the fighter to be 8000 feet down the runway causing the KC-135 to complete another approach. Therefore, the 8000 foot restriction, not the 1.5 mile minimum spacing, is the constraint in this situation.

Since the model was already set up to compute enroute separation, a new enroute separation was computed which would guarantee that the 8000 foot runway separation criteria would not be violated. Using the maximum speed the model allowed for a KC-135's approach and the slowest fighter runway clearing time yielded a minimum enroute separation distance of 2 miles. This distance is the minimum a heavy may be from the runway when a fighter lands.

Case 2: Fighter following a heavy KC-135. It takes the fighter 33 seconds to go 1.5 miles at 165 KCAS. Again, this minimum spacing would not allow the KC-135 sufficient time to be 8000 feet down the runway. Computing a new minimum spacing using the maximum speed the model allows for the fighter's approach and the slowest KC-135 runway clearing time yielded 2 miles. This distance is the minimum the fighter may be from the runway when the heavy lands.

Case 3: Heavy KC-135 following another heavy. Using the minimum enroute spacing of 1.5 miles does not allow the preceding KC-135 enough time to get off the runway. Computing a new minimum spacing using the maximum approach speed and minimum runway clearance time yields 1.8 miles. This distance is the minimum a KC-135 may be from the runway when the preceding KC-135 lands.

Because in each case a new minimum enroute spacing requirement existed, the model would now have to keep track of which type of aircraft was following the other and apply the

proper spacing as to when a particular type of aircraft needed to be slowed down. The model would also have to keep track of how many of each type of aircraft was being slowed down. These differences from the basic model would require about 70 lines of additional computer code.

Another change added to the expanded model was the addition of a different colored radar blip representing the KC-135 aircraft to the animation. In real life, controllers would know the call signs and types of aircraft on the approach. (Gray, 1992) The different color represents this knowledge.

The Expanded Model

The following describes, in detail, the simulation's computer code throughout the important FTR process given by line numbers. For a complete listing of the entire SIMSCRIPT model, see Appendix 1.

Lines 1-36: Define variables and variable types.

Lines 37-41: Initializing the animation.

Lines 41-49: If a KC-135 is sent to the FTR process, it is not an element (a two aircraft entity); a fighter may or may not have an element mate.

Lines 50-59: Randomly select a airspeed, dive angle, left or right error and compute the starting "R", the radial distance from the airbase for each airplane.

Lines 60-62: Place the aircraft at the IAF. If other aircraft are there, place behind them.

Lines 63-142: Set the minimum distance an aircraft can depart the IAF in trail with another aircraft. Since we have single fighters, elements of fighters, and KC-135s, there are six combinations which have a specified minimum distance.

Lines 143-163: Set the initial dive angle, and then once set, vary the dive angle within allowable limits (5.25°-6.5°).

Lines 164-176: Convert KCAS to KTAS. This conversion is not linear from the surface to 16,000 feet. Therefore, it is partitioned into smaller altitude blocks where a linear relationship exists.

Lines 177-188: Level aircraft from out of its dive and convert dive angle from degrees to radians.

Lines 189-194: Wind velocity (knots) for different altitudes.

Lines 195-197: Compute ground speed and also compute the vertical velocity, how fast the airplane dives measured in feet per second.

Lines 198-242: If left or right error is too great for a given distance, turn the aircraft back to course.

Lines 243-256: Recompute the new heading, error, x, and y position's. Never allow x or [y - field elevation] to go below 0.

Lines 257-262: If airplane has been instructed to slow down, and has already done so, reduce the variability in its airspeed.

Lines 263-267: The approach has a mandatory altitude at the DRAG point (see figure 1.), ensure aircraft is there.

Lines 268-275: Change the aircraft's airspeed within allowable limits, 295-310 KCAS.

Lines 276-281: Use the updated x, y, and error position's to compute a new radial distance for the aircraft.

Lines 282-293: Animation logic to place the aircraft at the proper position on the radar screen.

Lines 294-300: If element of fighters, split off wingman now.

Lines 301-320: At respective DECEL point, slow aircraft down to 180 KCAS. Different rates are used depending on aircraft type. Set set.speed flag to yes (1) when speed is set.

Lines 321-330: Allow speed to vary between 175-190 KCAS.

Lines 331-339: Place aircraft in file allowing separation distance to now be determined.

Lines 340-446: Compute the distance between aircraft when the radial distance is less than 10.4 miles and there is more than one aircraft below this distance. If distance between aircraft is less than required, depending on what type of aircraft are following the other, slow down the trailing aircraft to 165 KCAS and increment the number of aircraft slowed down by one. Num.slowed, numw.slowed, and numh.slowed keep track of the total number of aircraft slowed down, number of wingman slowed down, and number of KC-135s slowed down. Reset logic counters to 0.

Lines 447-454: If an aircraft's radial distance is less than 10.7 miles, set dive angle to the Instrument Landing System's (ILS) angle of 2.6°.

Lines 455-466: Place aircraft's radar return on the expanded scope. Step the model in 1 second time steps.

Lines 467-506: If an aircraft's radial distance is less than 4.7 miles (FAS on figure 1.), slow the aircraft down to its respective Final Approach Speed; 165 KCAS for the fighter's and 140 KCAS for the KC-135. Once this speed is set, airspeed will now vary.

Lines 507-513: If radial distance is less than 1.9 miles, i.e. on the runway, slow the aircraft to 30 KCAS.

Lines 514-518: Call routine "cycle" which computes aircraft separation distance once aircraft is at the approach end of the runway.

How Were the Results Obtained?

The model starts out idle and empty indicating that there is initially no activity on the approach. When the fighter recovery starts, the arrival rate of aircraft is assumed to be greater than the system can process through the approach so that aircraft stack up at the IAF. This has been this author's experience in over ten years of flying ASLAR approaches. This assumption was confirmed by all the other experts.

Also, since we were trying to compare the maximum capacity of the system to what was reported by Bryant & Associates, an airplane was assumed to be in a position to start the approach as soon as the minimum IAF separation distance had been attained by the preceding aircraft. Translating this maximum modeled capacity to an expected "real world" maximum capacity is a topic discussed in Chapter IV.

There were six possible trailing combinations that fighters and KC-135s could have on the approach:

- A fighter/fighter element following a single fighter.
- A fighter/fighter element following a fighter element.
- A KC-135 following a single fighter.
- A KC-135 following a fighter element.
- A fighter/fighter element following a KC-135.
- A KC-135 following a KC-135.

An objective of this research was to explore how these combinations might be affected by a wide variety of wind conditions. What winds were important to look at? It would have taken an inordinate amount of time to explore every possible wind condition and so a compromise solution was reached.

The first winds to be selected were the surface winds.

Surface winds that would be explored were:

- 10 knots of tailwind
- 0 knots, or calm winds
- 20 knots of headwind

The experts agreed this range of wind conditions would represent the winds most likely to be experienced by approaching aircraft. Calm winds were initially modeled as light and variable, less

than 5 knots of wind from any direction, but this was dropped as an option because it increased the complexity of the model, it slowed the model run time, and it did not change the mean value obtained for aircraft separation. It did increase the variance of the values, however.

With surface winds chosen, plausible winds at-altitude were chosen in 20 knot increments as shown by the shaded regions in Figure 5 (see next page). With the 14 values for the wind chosen for the six possible combinations, a minimum of 84 computer runs would be required.

Winds At Altitude

		-40	-30	-20	-10	0	10	20	30	40	60
Surface Winds	-10										
	0										
	20										

Figure 5. Winds

In each shaded box in Figure 5 there would be three values given from the computer runs:

- The mean final distance between aircraft
- The minimum IAF separation
- The percent of aircraft requiring controller slowdown

Why were these three values important and how were these values computed? To compute the mean final distance between aircraft,

the model had to first correctly model enroute separation and then determine where the minimum enroute separation occurred.

Modeling Enroute Separation. This researcher originally thought the model must compute the enroute separation at all times because, in real life, whenever controllers observe a conflict they slow the trailing aircraft. Since as many as 10 aircraft were capable of being on the approach at any one time, the computational ability required to do this quickly outpaced a personal computer -- the model now took three times longer to run than real life.

Rather than find a faster computer, an alternative solution was explored. Using knowledge from current ASLAR operations, this author used a starting point for a minimum IAF separation as 4 miles, the distance a fighter could depart behind another single fighter. The model would later show that the smallest IAF separation for any of the possible combinations of fighters and KC-135s was three miles. Since the maximum speed differential allowed by the model was about 30 knots, the earliest a conflict could occur would be around three minutes after the approach started. This equated to around 12-15 miles from the airport.

Starting to compute the separation distance at this point definitely helped with the speed the model ran but, unfortunately, presented another problem. This point on the approach was right in the middle of a fighter element's drag maneuver. Computing the separation here, of course, found the

majority of wingmen's aircraft with **less** than the required separation from their leader. Thus, according to the model's logic, a controller would instruct the wingman to slow down and increment the number of aircraft slowed down by one. This was clearly incorrect.

Therefore a new distance, closer to the airfield, needed to be found to start the computation. Since around 90% of the aircraft that fly ASLAR do so as elements, computing aircraft separation once the lead aircraft had slowed to 180 KCAS would ensure elements had enough time to complete their drag maneuver. This distance turned out to be 8.5 miles from the airport at Seymour Johnson AFB. With this distance now specified, the model ran smoothly and efficiently. Now that this problem had been solved, the next problem was to determine where in the instrument approach the enroute separation is minimized.

Minimum Enroute Separation. It was originally thought this minimum could occur at any time during the approach and the model's logic was initially designed to compare the current aircraft separation with a previously stored minimum separation. This quickly became unmanageable. As it turned out, this was not required.

Aircraft which fly the **exact** same speed profile during an approach will have the exact **time separation** at the runway that they had at the IAF despite the fact that they will not have the same distance separation. For example, what happens if one aircraft departs the IAF 15 seconds in trail with another?

Assuming both aircraft are flying 300 KCAS, which for this approach equates to 360 KTAS, controllers will see the required 1.5 miles minimum enroute spacing. (6 miles/min x .25 minutes = 1.5 miles)

However, as the lead aircraft slows to 180 KCAS at the designated DRAG point, the distance between aircraft decreases below the 1.5 mile minimum **even though** the aircraft are still separated by the same 15 seconds. This **assumes** the second aircraft also decelerates at exactly the same points as his leader which it should under ASLAR rules. ASLAR aircraft make a further speed reduction to their Final Approach Speed normally within 2-3 miles from the airport. A final speed reduction occurs on short final approach as aircraft transition from a flying to a landing speed. Therefore, any time the front aircraft is slower than the trailing aircraft, distance compression occurs; time compression does not.

By the time these two aircraft are on short final and both at 165 KCAS, this 15 second in-trail separation equates to only 4200 feet. This distance is clearly below the 9000 feet required and is the lowest computed value. We see, therefore, that the minimum enroute separation occurs when one aircraft is just landing and the other is on short final.

What happens, as it does in our model, when speed is allowed to vary on the approach? It turns out, for our specific approach, the minimum enroute separation still occurs in the same place. Why is that? Lets look at what happens to aircraft

as they approach the airbase. The **fastest** final approach speed the model allows a fighter inside of 2.8 miles from the runway is 175 KCAS. If the trailing aircraft is beyond 2.8 miles from the runway, the model only allows a **minimum** of 175 KCAS so distance compression continues until the trailing aircraft also reaches the 2.8 mile point and is allowed to slow down.

When the trailing aircraft reaches 2.8 miles, the front aircraft is now approximately 20 seconds from landing. Twenty seconds is insufficient time, given the maximum 15 knot speed differential between the aircraft, to change the enroute separation significantly. The model, therefore, determines when an aircraft is over the runway and then computes the distance to the trailing aircraft. This is the mean final distance given in the tables.

Of what importance are the mean final distance values? Remember, the model is run for only specified wind conditions. Under real world conditions, the IAF separation distance will be initially set for the actual wind conditions. If the controllers sees that final distances are greater than expected, the controller has the option to reduce the IAF separation by one mile. If, after the reduction in IAF separation, the number of aircraft being slowed down exceeds 5%, the controller knows the original IAF separation should be used.

Could not then this entire research effort been reduced to determining how long it takes the slowest possible aircraft at landing speeds to go 1.5 miles and then convert this time to a

distance for the fastest aircraft to depart the IAF? Unfortunately, as outlined below, it was not that easy. It did, however, provide an initial approximations for IAF separation distances.

As aircraft proceed down the approach they interact with each other. Since aircraft can not pass each other on an approach, faster aircraft are forced to reduce speed behind slower aircraft. This spreads out what appeared to be an orderly departure of aircraft from the IAF. A good analogy is a mountain climbing expedition. While a team may depart in 10-foot intervals, it rather quickly spreads to the allowable length of their ropes. For this reason, my initial approximation for IAF separation usually had to be increased by 1 to 2 miles in order to account for the variability in the actual speeds flown by the aircraft.

Minimum IAF Separation. The controllers primary input into ASLAR, and the key to making ASLAR work smoothly, is properly setting the minimum IAF separation distance between trailing aircraft. How then did the model determine what the minimum IAF separation should be?

At the start of each computer run, an integer value for IAF separation was selected by the technique described previously. The experts had agreed that IAF separation distances had to be integer values because a value of 7.54 miles meant nothing to a controller because his radar does not have that kind of resolution at 30 to 35 miles. The controller would

instead round 7.54 up to 8 miles. Seven miles would not be chosen as this value was less than the minimum and the number of aircraft forced to slow down would exceed the 5% level.

After 250 aircraft had been processed through the model, the output, displayed as a histogram similar to Figure 4, was reviewed. Additional information on these histograms, and not shown on Figure 4, was the number of aircraft requiring to be slowed down. If this number was greater than 12, meaning more than 5% of the aircraft had to be slowed down given 250 aircraft had been run through the system, then the IAF distance was increased by one unit and the model was run again. Likewise, if there were no aircraft required to be slowed down, the IAF distance was reduced by one unit. This iterative process was used to get the minimum acceptable IAF separation distance for all 84 wind and trailing aircraft combinations.

The importance of listing in the tables the percent of aircraft requiring controller slowdown is to give controllers a feeling for how the approach should proceed for a given set of wind conditions. If the table shows very few aircraft should be slowed down for a given IAF separation but controller workload is becoming excessive, controllers should then increase the minimum IAF separation by one mile.

The results from all the model runs are presented in the next chapter.

IV. SOLUTIONS AND RESULTS

The results of this research presented in this chapter are a summary of over 300 individual computer runs taking over 100 hours of actual computer time. The data from these computer runs are presented in six tables. There is a table for each of the trailing combinations of fighters and heavy KC-135s possible during an approach. Each table shows the minimum IAF separation, average distance between aircraft at landing, and percent of aircraft requiring controller intervention for all specified wind conditions.

After the tables there is a comparison of the model's results with the initial ASLAR capacity stated by Bryant and Associates. It was previously postulated that one of the reasons for ASLARs mixed results may have been an overly optimistic expectation of its ability to land aircraft.

The Tables

The tables were designed to aid controllers in quickly computing the correct IAF separation once the winds affecting the approach were known. Where do controllers get these values for the winds?

Air traffic control has a direct readout of the surface winds which the controller is made aware of. Then, when the first aircraft approaches the IAF for landing, the pilot can give controllers the winds at altitude. Now it is a simple

matter of finding the nearest tabled value for winds at altitude, proceed down to the correct surface winds, and read off the IAF separation distance.

On the tables, positive wind values are considered direct headwinds and negative values are considered direct tailwinds. Since the tables don't cover all possible ranges of winds, interpolation may be required. Distances between given wind values should be considered linear. If an interpolated value for IAF separation is not an integer value, it is recommended that the controller initially round up to the higher integer value as an initial starting point. Then after monitoring the approach flow, if it seems to be spread out more than anticipated, the next lower integer value for IAF separation may be chosen.

Except for the KC-135 following a single fighter, a definite pattern can be noted in the tables. The IAF separation distance is a minimum in the upper right corner of the table and increases as you proceed down and to the left. This is explained by the effect windshear has on the ground speed of an approaching aircraft. A net increase in wind reduces an aircraft's groundspeed which will compress distances between aircraft; a net decrease will spread the aircraft farther apart.

For example, compare the values in Table 1 (see next page) for -10 knots of wind on the surface and -10 and -30 knots of wind at altitude. In the first case, there is no net

FIGHTER/FIGHTER ELEMENT FOLLOWING A FIGHTER

WINDS AT ALTITUDE

		-40	-30	-20	-10	0	10	20	30	40	50
SURFACE WINDS	-10		4.0 1.89 3.6		4.0 2.0 0.0		4.0 2.12 0.0		4.0 2.25 0.0		
	0	5.0 2.18 0.0		5.0 2.3 0.0		4.0 1.94 4.0		4.0 2.05 0.0		4.0 2.19 0.0	
	20			5.0 2.01 0.5		5.0 2.13 0.1		5.0 2.26 0.0		5.0 2.42 0.0	4.0 2.06 0.0

IAF SEPARATION (nm.)
MEAN FINAL DISTANCE
PERCENT REQUIRING CONTROLLER SLOWDOWN

Table 1

increase or decrease in groundspeed and we get a base line separation of 2.0 miles. In the second case, by going from 30 knots of tailwind to only 10, we experience an increase in wind velocity of 20 knots. Note that aircraft separation is reduced to 1.89 miles even though the IAF separation distance is the same.

Looking at the same example but comparing the base line separation to the 10 knot headwind column, we see aircraft separation has indeed increased to 2.12 miles. This is because the aircraft experiences a wind shear going from 10 knots headwind to 10 knots tailwind causing ground speed to increase 20 knots.

Fighter/Fighter Element Following A Single Fighter

(Table 1) The case of a single fighter following another single fighter in an ASLAR approach is quite rare since fighters normally fly as two- or four-aircraft flights. However, in a wartime scenario a lead or wingman could be shot down causing a single aircraft to arrive at the IAF. The reason a fighter element is able to depart the same IAF separation distance as a single fighter is that the fighter lead flies the same speed profile as the single fighter.

Fighter/Fighter Element Following A Fighter Element

(Table 2 next page) The majority of the computer coding effort in this research went into perfecting the case of a fighter element following another on an approach since this is the normal operational mode of ASLAR. This was also the configuration which was the hardest to arrive at an IAF separation between elements. This required separately keeping track of the number of wingman who were told to slowdown versus the number of leaders.

If an element of fighters were on the approach, independent of any other aircraft, and followed the proper procedures there would always be a small percentage of wingman who would have to slow down behind their leaders given the variability in the two aircraft's speeds. This result, which the model showed, was confirmed by my flying experiences and varied anywhere between 0% and 2.5% depending on wind

FIGHTER/FIGHTER ELEMENT FOLLOWING FIGHTER ELEMENT

WINDS AT ALTITUDE

SURFACE WINDS		-40	-30	-20	-10	0	10	20	30	40	60
	-10		8.0 3.94 0.8		8.0 4.19 0.0		8.0 4.45 0.0		7.0 4.13 0.0		
	0	9.0 4.10 0.0		8.0 3.82 4.8		8.0 4.06 0.2		8.0 4.34 0.0		7.0 4.02 1.2	
	20			10.0 4.26 0.0		9.0 4.04 1.2		9.0 4.33 0.0		8.0 4.08 2.0	8.0 4.4 0.0

IAF SEPARATION (nm.)

MEAN FINAL DISTANCE BETWEEN ELEMENTS

PERCENT OF ELEMENTS REQUIRING CONTROLLER SLOWDOWN

Table 2

conditions. Therefore, if only the number of aircraft being told to slow down by controllers were recorded, element separation could be increased to 100 miles and still never drive the percent of aircraft having to slow down to zero.

With the number of lead aircraft forced to slow down recorded separately, a correct IAF separation distance could be computed. Reducing the IAF separation below a certain distance caused a marked increase in not only the numbers of leaders who had to be slowed down but also the number of wingman. This result makes sense because as the number of leads slowing down increases, separation with their wingman who must then also slow down is reduced, which reduces the separation between the

wingman and the element lead behind him, and so on. Now instead of almost independent fighter elements on the approach, which is true when there is no controller intervention, there is a high degree of correlation between flights.

The distance given in the chart is between element leads, not between aircraft as in the preceding chart. The reason is that the average distance between a wingman and his lead is different than the distance between that same wingman and the lead of the trailing element. Since we wanted to compute the IAF separation between flight leads, the same separation was recorded for a mean final distance.

Also, as the previous chart showed, a single fighter can be included in this chart because the single fighter follows the same speed profile as the element lead.

Heavy KC-135 Following A Single Fighter

(Table 3 next page) This chart is rather unique because the IAF separation distances are the same value no matter what winds are blowing. The reason is that the KC-135 slows down five miles earlier than the fighter and it never has a chance to cause a conflict with the fighter.

The minimum IAF distance could not be reduced to two miles for two reasons. First there was the chance that the two aircraft would violate the 1.5 mile separation criteria very early in the approach, which was not desired. Secondly, on the

radar scope at ranges of between 20 and 30 miles, two miles looks a lot like 1.5 miles. (Gray, 1992)

HEAVY FOLLOWING SINGLE FIGHTER

WINDS AT ALTITUDE

SURFACE WINDS		-40	-30	-20	-10	0	10	20	30	40	60
	-10		3.00 2.77 0.0		3.00 2.84 0.0		3.00 2.94 0.0		3.00 3.04 0.0		
	0	3.0 2.68 0.0		3.00 2.72 0.0		3.00 2.82 0.0		3.00 2.91 0.0		3.00 3.03 0.0	
	20			3.00 2.66 0.0		3.00 2.74 0.0		3.00 2.84 0.0		3.0 2.91 0.0	3.0 3.01 0.0

IAF SEPARATION (nm.)
MEAN FINAL DISTANCE
PERCENT REQUIRING CONTROLLER SLOWDOWN

Table 3

Heavy KC-135 Following A Fighter Element

(Table 4, next page) The process of figuring out the correct IAF separation for this configuration was similiar to that of an element of fighters following another. As previously noted, it was not sufficient to keep track of only the total number of aircraft being slowed down, but also how many of each type.

Since the winds affect a fighter element more than just a single element, plus the increased inherent variability of three aircraft interacting versus only two, the IAF separation

HEAVY FOLLOWING FIGHTER ELEMENT

WINDS AT ALTITUDE

SURFACE WINDS		-40	-30	-20	-10	0	10	20	30	40	50
	-10		7.0 4.85 0.0		6.0 4.49 1.5		6.0 4.68 0.0		5.0 4.36 4.0		
	0	7.0 4.60 0.0		7.0 4.80 0.0		6.0 4.46 2.0		6.0 4.66 0.0		6.0 4.86 0.0	
	20			7.0 4.49 2.0		7.0 4.62 0.8		7.0 4.85 0.0		6.0 4.60 1.5	6.0 4.78 0.0

IAF SEPARATION (nm.)

MEAN DISTANCE BETWEEN FIGHTER LEAD AND HEAVY

PERCENT OF HEAVIES REQUIRING CONTROLLER SLOWDOWN

Table 4

distances are not constant values like they were when the KC-135 followed a single fighter. Also note the distances on final are between the lead fighter and the KC-135, not the wingman and the KC-135.

Fighter/Fighter Element Following A KC-135

(Table 5, next page) The results here are noteworthy in that the distance a fighter element must start an approach behind the KC-135 is only one mile more than if the same fighter element were following another fighter element. This is significant because it shows that, if Air Force officials decide to let KC-135s participate in ASLAR, a delay of less than 1.5 minutes is all that is needed to allow KC-135s to land in the middle of a fighter recovery. A delay of this length equates to

FIGHTER/FIGHTER ELEMENT FOLLOWING SINGLE HEAVY

WINDS AT ALTITUDE

SURFACE WINDS		-40	-30	-20	-10	0	10	20	30	40	60
	-10		9.0 2.70 0.0		9.0 2.99 0.0		8.0 2.67 0.2		8.0 2.99 0.0		
	0	10.0 2.70 0.0		9.0 2.51 0.0		9.0 2.74 0.0		8.0 2.53 0.0		8.0 2.79 0.0	
	20			11.0 2.63 0.8		10.0 2.45 3.0		10.0 2.78 0.0		9.0 2.51 1.5	9.0 2.94 0.0

IAF SEPARATION (nm.)

MEAN DISTANCE BETWEEN HEAVY AND FIGHTER/FIGHTER LEAD

PERCENT OF FIGHTER/FIGHTER LEADS REQUIRING CONTROLLER SLOWDOWN

Table 5

about 100 to 150 extra pounds of fuel required by the fighters. Granted, some fighters may not even be able to wait this small amount, but somewhere in the recovery the KC-135 can be brought in to land. KC-135s should no longer have to wait until all the fighters have landed.

Heavy KC-135 Following A KC-135

(Table 6, next page) This combination is the least likely of the six to ever be experienced during actual operations since KC-135s do not fly in elements, as do fighters. None-the-less, as other heavy aircraft are included in ASLAR with similiar flying characteristics, such as the C-141 heavy cargo aircraft, this combination has a possibility of occuring and so it was modeled.

HEAVY FOLLOWING HEAVY

WINDS AT ALTITUDE

SURFACE WINDS		-40	-30	-20	-10	0	10	20	30	40	60
	-10		6.0 2.52 0.0		6.0 2.70 0.0		5.0 2.32 1.2		5.0 2.49 0.0		
	0	6.0 2.26 0.8		6.0 2.40 0.0		6.0 2.57 0.0		5.0 2.22 2.0		5.0 2.39 0.0	
	20			7.0 2.4 0.3		7.0 2.57 0.3		6.0 2.29 0.8		6.0 2.47 0.0	5.0 2.16 4.0

IAF SEPARATION (nm.)

MEAN FINAL DISTANCE

PERCENT REQUIRING CONTROLLER SLOWDOWN

Table 6

Now that we have the values from the model for all the above combinations, how do these results compare to what the original study done by Bryant & Associates?

The Model versus Bryant & Associates versus Reality

Bryant and Associates briefed Air Force officials that ASLAR had the capability to land 80 aircraft per hour. What arrival rates does the model compute? Are either of these estimates really accurate when compared to the real world? Although this researcher could not find a specific mention as to what fighter combination or wind condition was used in coming up with the Bryant & Associates estimate; it was assumed they used calm wind conditions and elements of fighters in trail.

The model shows the IAF separation for fighter elements in trail is eight miles. This equates to elements departing the IAF in 1.33 minute intervals. (8 miles / 6 miles per minute at 360 KTAS = 1.33 minutes) This means 45 elements can land in one hour which translates to an arrival rate of 90 aircraft per hour in steady state conditions.

If one assumes that the hourly landing rate of the system should instead be computed for how many aircraft can land in one hour given the system is empty at time zero, the arrival rate is reduced to 81 aircraft per hour. This is because it takes approximately six minutes for the first aircraft to go from the IAF to the runway. Since both of these rates are actually greater than what Bryant & Associates briefed, the model seemed to confirm their initial estimates. Or does it? What if neither of these rates are really representative of what happens during day-to-day ASLAR operations?

Because the model was trying to compute the maximum capability of ASLAR, which in turn would place the most stress on the system, certain assumptions needed to be made. The model assumed there was always a fighter element "hovering" at the IAF ready to leave **exactly** when the preceding element was eight miles down track; this is definitely not what happens in real life.

First, another element may be inbound to the IAF, but not yet at the IAF, and so it can not leave **exactly** at the specified in-trail distance. This means the controller already sees a

distance of greater than eight miles. Secondly, if an element is at the IAF but does not have the proper spacing, another holding turn is required. In bad weather conditions, this turn will take a minimum of 1.5 minutes.

For these reasons, a more realistic expected distance between fighter elements is around 9.5 to 10 miles. This translates to a stabilized flow rate of between 72 to 75 aircraft per hour. The rate of landing aircraft in a one hour period starting idle is 64 to 68 aircraft. Are these arrival rates then realistic? The answer is, "it depends."

For simple approaches, like the one at Seymour Johnson AFB which is a straight-in, landing rates of up to 75 aircraft might be achieved. But not all approaches are simple. There are approaches that require aircraft to arc the field at some fixed distance before establishing a straight-in final. These will have much greater IAF departure distances because of the added variability of aircraft being either inside, or outside, the intended arcing distance. This will decrease the arrival rate even further.

Therefore, for all the reasons mentioned, this researcher believes that when Bryant & Associates projected an ASLAR arrival rate of 80 aircraft per hour, they were being too optimistic.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research effort investigated the current ASLAR instrument approach system at Seymour Johnson AFB along with the proposed changes that the Air Force wishes to implement. It started out by gathering a group of experts to detail the assumptions that would go into building the computer model. Once a flow chart mapped out the basic logic flow of the primary process, a very basic computer model of Runway 26 operations was built to get a better understanding of the many variabilities that go into building a model.

This single fighter following a single fighter simulation helped in finding both syntax and logic errors. It also showed that the original model formulation had to be changed because of the erratic movement of the animated aircraft. Once the basic model was verified and validated, a more complex model was built with elements of fighters, along with controller intervention. This helped ensure the assumptions and variables modeled accurately portrayed ASLAR as it was currently being flown.

Measurements from this model were used to compute an expected landing rate which was compared to a previous study. Even the model showed that landing rates, such as were briefed in 1983, **were possible**. Perhaps a more thorough understanding of the many intricacies of ASLAR led to the conclusion that the

original estimates by Bryant & Associates were a little too optimistic.

The model was then expanded to include heavy KC-135 aircraft. The model design was simplified by many of the decisions already made by Air Force officials, but still presented obstacles to be overcome. The model looked at joint ASLAR operations over an entire instrument approach while the winds were varied over a range of values. Many computer runs were completed to explore possible reasons why KC-135s should not be included into ASLAR. These reasons may have been hidden during the brief flying demonstrations but would have surfaced during an extensive, initial test and evaluation phase of joint flying operations. The benefit of using the simulation model is that, hopefully, the time from initial testing to final implementation of joint ASLAR operations would be greatly reduced with a substantial savings in cost. This is because the model had already explored, and corrected for, conditions aircraft might experience in their flying operations.

Recommendations

The bottom line questions for this research were:

Are joint ASLAR operations feasible?
Can procedures for joint ASLAR operations be developed?
Are joint ASLAR operations safe?

This research showed that joint ASLAR operations are indeed feasible for fighters and the KC-135. The addition of other heavy cargo and tanker aircraft could easily be added if

their flying characteristics were not significantly different from the KC-135. The amount of effort to model these additional aircraft would pose few problems. However, Air Force officials were correct in trying to minimize the amount of variance in the approach speeds between the KC-135 and the fighters. This keeps ASLAR simple for controllers to monitor and control and it is recommended that this policy be extended when new aircraft are permitted to fly ASLAR approaches.

As to the development of these new procedures, the tables given in the previous chapter specify the primary controller input into ASLAR, the IAF separation distance. With this input, along with the recommended changes to the way KC-135s should fly ASLAR approaches discovered during the flying demonstration, the final procedures are pretty much established. Additional testing would modify them to some degree since even this model did not model every possible variable. Hopefully, these changes would be minor in nature.

The final question of the safety of these new procedures is probably the most important one. When AFCC officials brief the ACC Director of Operations, a four-star general, safety will be paramount in his mind. As both a pilot and an operations researcher, I am acutely aware that this research may well sway a decision on how, or if, joint ASLAR operations are conducted.

My only reservation with the new procedures are the reduced distance fighter aircraft will experience behind KC-135 aircraft. These concerns don't just center on the reduced time

between landings, but on the distinctly different way fighter and cargo/tanker aircraft fly the last mile of the approach.

Pilots are taught from day one of pilot training about the hazards of wake turbulence behind heavy cargo and tanker aircraft. The rule of thumb taught when this author went to pilot training in 1985 was to avoid landing behind a KC-135, in a fighter aircraft, for two minutes to allow the wake turbulence to dissipate. Under the procedures modeled, this time can be reduced to 45 seconds, although on average it will be around one minute.

What is different about how a fighter and a KC-135 fly the final one mile of an approach? Fighter aircraft are instructed to land within the first 1000 feet of the runway with 300 to 500 feet being the optimum. Tanker aircraft usually land 1500 to 2000 feet down the runway. This means tanker aircraft are still flying, and generating their greatest wake turbulence, right over the point where the fighter intends to touchdown. This fact, along with the reduced time separation, should at least raise a caution flag.

A suggested approach for initial joint testing of ASLAR operations would be to add two to three miles to the minimum IAF separation distances given in the tables whenever fighters follow a KC-135. This would still reduce the current delay to fighter aircraft and allow all pilots a period to get comfortable with reduced separations. This distance could be reduced to the tabled values, in increments of one mile, as Air

Force officials become confident that there is no increased safety hazard to fighter aircraft.

In conclusion, this researcher believes joint ASLAR operations should be initiated, additional cargo and tanker aircraft should be added as soon as possible, and a cautious approach taken with respect to the new reduced separation between fighter and tanker aircraft.

Areas For Further Study

This research has laid the foundation for further study in joint ASLAR operations by modeling a single, straight-in approach. Additional approaches should be modeled, including arcing approaches. Modeling arcing approaches would give Air Force officials a better feel for how heavy and fighter aircraft interact when aircraft position variability is much greater.

This research did not attempt to model wake turbulence and its recommendations show the cautious approach taken because wake turbulence's effects are unknown. Research compiled from the Federal Aviation Administration and NASA could provide the needed knowledge.

Further research could examine how the results given in Chapter IV change as additional data is provided from initial testing of joint ASLAR operations.

APPENDIX A: THE SIMSCRIPT MODEL

```
1 preamble
2
3 normally mode i undefined
4
5 the system owns a radar, and owns a fix
6
7 resources include iaf
8
9 processes include ftr.gen,
10     distance
11     every heavy.gen has a q
12     every ftr has a r,
13         a rad,
14         a heavy,
15         a type,
16         a element,
17         a cal.as,
18         a speed.set,
19         a speed.set2,
20         a wingman
21         and may belong to the radar,
22         and may belong to the fix
23
24     every ftr1 has a r1
25
26     every ftr2 has a kcas2,
27         a x2,
28         a y2,
29         a r,
30         a error2,
31         a phi2,
32         a rad,
33         a type,
34         a cal.as,
35         a speed.set,
36         a speed.set2,
37         a wingman
38         and may belong to the radar
39
40     every ftr3 has a r3
41
42     every heavy2 has a r
43
44 events include stop.sim
45
46 define d as a real, 1-dimensional array
47 define dist.btw as a real, 1-dimensional array
48
```

```

49 define hours to mean units
50     define minutes to mean /60 hours
51     define seconds to mean /3600 hours
52
53 define x2,
54     y2,
55     r,
56     r1,
57     r3,
58     rad as double variables
59
60 define kcas2,
61     cal.as,
62     error2,
63     phi2,
64     d1 as real variables
65
66 define i,
67     q,
68     heavy,
69     type,
70     element,
71     el,
72     speed.set,
73     speed.set2,
74     num.slowed,
75     numw.slowed,
76     numh.slowed,
77     count,
78     time,
79     wingman as integer variables
80
81 define radar1 and runway as pointer variables
82 dynamic graphic entities include ftr,
83                                     ftr1,
84                                     ftr2,
85                                     ftr3
86
87 display variables include d1
88
89 end

```

```
1 main
2
3 create every iaf(1)
4 let u.iaf(1) = 1
5 el = 109 '' Seymour Johnson field elevation
6
7 activate a ftr.gen in 10 seconds
8 activate a heavy.gen in 51 seconds
9 show radar1 with "radar1.frm"
10 display radar1
11 show runway with "runway10.frm"
12 display runway
13 reserve d(*) as 10
14 reserve dist.btw(*) as 5
15 display d1 with "d1"
16
17 start simulation
18
19 end
```

```

1 routine cycle
2 define airplane as a pointer variable
3 define j, max.dim as integer variables
4
5 let max.dim = 10
6 if n.radar le 1
7     for j = 1 to max.dim
8         let d(j) = 0
9 always
10 if n.radar gt 1
11     for each airplane in radar
12         do
13             let j = j + 1
14             if j lt 2 'n.radar
15                 let d(j) = rad(s.radar(airplane)) -
                    rad(airplane)
16             else
17                 let d(n.radar) = 0
18             always
19         loop
20 always
21 if n.radar lt max.dim
22     for j = n.radar + 1 to max.dim
23         let d(j) = 0
24 always
25 d1 = d(1)
26 return
45 end

```



```

1 process ftr given heavy
2
3 ''process simulates the HI TAC 2 RW 26 (ASLAR)
4 ''at Seymour Johnson AFB
5 define kcas,
6     ktas,
7     set.dive,
8     change,
9     angle,
10    dive,
11    dive.del,
12    vvi,
13    error,
14    error.del,
15    phi,
16    phi.del,
17    theta,
18    wind as real variables
19
20 define out,
21     heavy,
22     dist.past,
23     split,
24     in.set,
25     set.speed,
26     set.speed1,
27     set.speed2,
28     set.speed3 as integer variables
29
30 define x,
31     y,
32     r,
33     dist,
34     ground.speed as a double variable
35
36 define airplane as a pointer variable
37
38 d1 = 0
39 vxform.v = 1
40 call setworld.r(0, 50, 0, 35)
41
42 type(ftr) = heavy
43 wingman(ftr) = 0
44 if heavy = 1
45     element = 0
46 else
47     element = 1
48 always
49
50 kcas = triang.f(295, 300, 310, 2)
51 angle = uniform.f(5.25, 6.5, 1)
52 dive = -1

```

```

53 phi = uniform.f(-5., 5., 6)
54 y = 11000
55 r = 33.73515
56 x = sqrt.f( (r**2) - (((y - el)/6076)**2) )
57 error = uniform.f(-2., 2, 5)
58 r = sqrt.f( (x**2) + (((y-el)/6076)**2) + (error**2) )
59
60 file the ftr in the fix
61 request 1 iaf(1)
62
63 dist = r
64
65 while r gt .5
66   do if n.fix gt 1
67     'single fighter followed by fighter/fighters
68     if element(f.fix)=0 and type(f.fix)=0 and
69       type(s.fix(f.fix))=0
70       if dist - r ge 3 and dist.past = 0
71         relinquish 1 iaf(1)
72         dist.past = 1
73         remove the first ftr from the fix
74       always
75     always
76   always
77
78   if n.fix gt 1
79     'single heavy followed by single heavy
80     if element(f.fix)=0 and type(f.fix)=1 and
81       type(s.fix(f.fix))=1
82       if dist - r ge 5 and dist.past = 0
83         relinquish 1 iaf(1)
84         dist.past = 1
85         remove the first ftr from the fix
86       always
87     always
88   always
89
90   if n.fix gt 1
91     'element of fighters followed by fighter/fighters
92     if element(f.fix)=1 and type(f.fix)=0 and
93       type(s.fix(f.fix))=0
94       if dist - r ge 9 and dist.past = 0
95         relinquish 1 iaf(1)
96         dist.past = 1
97         remove the first ftr from the fix
98       always
99     always

```

```

101      ''single fighter followed by single heavy
102      if element(f.fix)=0 and type(f.fix)=0 and
          type(s.fix(f.fix))=1
103          if dist - r ge 3 and dist.past = 0
104              relinquish 1 iaf(1)
105              dist.past = 1
106              remove the first ftr from the fix
107          always
108      always
109  always
110
111  if n.fix gt 1
112      ''element of fighters followed by single heavy
113      if element(f.fix)=1 and type(f.fix)=0 and
          type(s.fix(f.fix))=1
114          if dist - r ge 6 and dist.past = 0
115              relinquish 1 iaf(1)
116              dist.past = 1
117              remove the first ftr from the fix
118          always
119      always
120  always
121
122  if n.fix gt 1
123      ''single heavy followed by fighter/fighters
124      if type(f.fix)=1 and type(s.fix(f.fix))=0
125          if dist - r ge 9 and dist.past = 0
126              relinquish 1 iaf(1)
127              dist.past = 1
128              remove the first ftr from the fix
129          always
130      always
131
132  else
133
134      if n.fix gt 0
135          if dist - r ge 12 and dist.past = 0
136              relinquish 1 iaf(1)
137              dist.past = 1
138              remove the first ftr from the fix
139          always
140      always
141  always
142
143  if r gt 18
144      if dive lt angle and set.dive = 0
145          dive = dive + 1.25 ''increase dive angle at
          1.25 degress/sec
146          if dive gt angle
147              dive = angle
148              set.dive = 1
149      always

```

```

151         if dive le 0
152             dive = 0
153         else
154             dive.del = uniform.f(-.25, .25, 1)
155             if ((dive + dive.del) gt 6.5) or ((dive +
                dive.del) lt 5.25)
156                 dive = dive - dive.del
157             else
158                 dive = dive + dive.del
159             always
160         always
161     always
162 always
163
164     'convert kcas to ktas
165     if y le 16000 and y gt 14000
166         ktas = (kcas * 376.0/300) - (.00560 * (16000 - y))
167     always
168
169     if y le 14000 and y gt 8000
170         ktas = (kcas * 364.8/300) - (.00475 * (14000 - y))
171     always
172
173     if y le 8000 and y gt 5000
174         ktas = (kcas * 336.3/300) - (.005 * (8000 - y))
175     always
176
177     if y le 5000 and y gt 0
178         ktas = (kcas * 321.4/300) - (.00428 * kcas/300 *
                (5000 - y))
179         if y le 2650 and y gt 2500 and dive gt 0 and r gt
                12.44582
180             dive = dive - 1
181             if dive le 0
182                 dive = 0
183             always
184         always
185     always
186
187     theta = dive/360 * 2 * pi.c
188
189     if r gt 1.93515 and y gt 4000
190         wind = 60
191     else
192         wind = 20
193     always
194
195     ground.speed = (ktas-wind) * cos.f(theta)/3600 'in
                nautical miles/sec
196     vvi = ktas * sin.f(theta) * (6076/3600) 'in ft/sec
197

```

```

198      ''centering aircraft error function
199      if r gt 30 and error gt 1.75
200          phi = -5
201      always
202      if r gt 30 and error lt -1.75
203          phi = 5
204      always
205      if r gt 25 and r lt 30 and error gt 1.4
206          phi = -4
207      always
208      if r gt 25 and r lt 30 and error lt -1.4
209          phi = 4
210      always
211      if r gt 20 and r lt 25 and error gt 1.1
212          phi = -4
213      always
214      if r gt 20 and r lt 25 and error lt -1.1
215          phi = 4
216      always
217      if r gt 15 and r lt 20 and error gt .8
218          phi = -4
219      always
220      if r gt 15 and r lt 20 and error lt -.8
221          phi = 4
222      always
223      if r gt 10 and r lt 15 and error gt .5
224          phi = -3
225      always
226      if r gt 10 and r lt 15 and error lt -.5
227          phi = 3
228      always
229      if r gt 5 and r lt 10 and error gt .25
230          phi = -2
231      always
232      if r gt 5 and r lt 10 and error lt -.25
233          phi = 2
234      always
235      if r gt 4.1
236          phi.del = uniform.f(-.3, .3, 6)
237      else
238          phi.del = 0
239          phi = 0
240          error = 0
241      always
242
243      phi = phi + phi.del
244      error.del = ground.speed * sin.f(phi*2*pi.c/360)
245      error = error + error.del
246      let x = x - ground.speed * cos.f(phi*2*pi.c/360)
247      let y = y - vvi
248

```

```

250     let x = 0
251     always
252     if (y - el) le 0
253         let y = el
254         dive = 0
255     always
256
257     if speed.set2(ftr) = 1
258         change = uniform.f(-.3, .3, 3)
259     else
260         change = uniform.f(-.75, .75, 3)
261     always
262
263     if r gt 17.73515 and y lt 2500
264         y = 2500
265         dive = 0
266     always      Line 267 deleted; a blank line
267     if r gt 17.73515 or (r gt 12.73515 and heavy = 0)
268         if (kcas + change gt 310) or (kcas + change lt
269             295)
270             kcas = kcas - change
271         else
272             kcas = kcas + change
273         always
274     always
275
276     if r le 1.93515 and heavy = 1
277         r = r - .0329164
278     else
279         let r = sqrt.f( ((y - el)/6076)**2 + x**2 +
280             error**2 )
281     always
282
283     rad(ftr) = r
284     if r gt 3.93515
285         if heavy = 0
286             show ftr with "ftr"
287         else
288             show ftr with "heavy"
289         always
290         let location.a(ftr) = location.f(37.5 + error, r)
291     else
292         erase ftr
293     always
294
295     if r le 17.73515 and split eq 0 and element eq 1
296         split = 1
297         if heavy = 0
298             activate a ftr2 giving kcas, x, y, r, error,
299                 phi now
300     always
301     always

```

```

300
301     if r le 17.73515 and r gt 4.73515 and heavy = 1 and
           set.speed1 = 0
302         if kcas gt 180
303             kcas = kcas - 2.05
304             if kcas lt 180
305                 kcas = 180
306                 set.speed1 = 1
307             always
308         always
309     always
310
311     if r le 12.73515 and r gt 4.73515 and heavy = 0 and
           set.speed = 0
312         if kcas gt 180
313             kcas = kcas - 4
314             if kcas lt 180
315                 kcas = 180
316                 set.speed = 1
317             always
318         always
319     always
320
321     if (r lt 17.73515 and r gt 4.73515 and heavy = 1 and
           set.speed1 = 1)
322         or
323         (r lt 12.73515 and r gt 4.73515 and heavy = 0 and
           set.speed = 1)
324
325     if ((kcas + change) gt 190) or ((kcas + change) lt
           175)
326         kcas = kcas - change
327     else
328         kcas = kcas + change
329     always
330 always
331
332 if r le 10.48515 and in.set = 0
333     file the ftr last in radar
334     in.set = 1
335 always
336
337 cal.as(ftr) = kcas
338 wait .0001 seconds
339
340 if r le 10.48515
341     count = count + 1
342 always
343

```

```

344     if n.radar gt 1 and count = n.radar
345         for each airplane in radar
346             do
347                 let i = i + 1
348                 if i lt n.radar
349                     dist.btw(i) = rad(s.radar(airplane)) -
                        rad(airplane)
350
351                     ''fighter behind fighter
352                     if (dist.btw(i) lt 1.55 or
                        speed.set(s.radar(airplane)) = 1)
353                         and
354                         speed.set2(s.radar(airplane)) = 0
355                         and
356                         type(s.radar(airplane)) = 0
357                         and
358                         type(airplane) = 0
359                         and
360                         (cal.as(s.radar(airplane)) gt 174. or
361                         speed.set(s.radar(airplane)) = 1)
362                         speed.set(s.radar(airplane)) = 1 ''drops
                        kcas to 165
363                         cal.as(s.radar(airplane)) =
                        cal.as(s.radar(airplane)) - 3
364                         if (cal.as(s.radar(airplane)) lt 165)
365                             cal.as(s.radar(airplane)) = 165
366                             speed.set2(s.radar(airplane)) = 1
                        ''for speed changes
367                             num.slowed = num.slowed + 1
368                             if wingman(s.radar(airplane)) = 1
369                                 numw.slowed = numw.slowed + 1
370                             always
371                                 always
372                             always
373
374                     ''heavy behind fighter
375                     if (dist.btw(i) lt 2. or
                        speed.set(s.radar(airplane)) = 1)
376                         and
377                         speed.set2(s.radar(airplane)) = 0
378                         and
379                         type(s.radar(airplane)) = 1
380                         and
381                         type(airplane) = 0
382                         and
383                         (cal.as(s.radar(airplane)) gt 174. or
384                         speed.set(s.radar(airplane)) = 1)
385                         speed.set(s.radar(airplane)) = 1 ''drops
                        kcas to 165
386                         cal.as(s.radar(airplane)) =
                        cal.as(s.radar(airplane)) - 3
387                         if cal.as(s.radar(airplane)) lt 165
388                             cal.as(s.radar(airplane)) = 165

```



```

389         speed.set2(s.radar(airplane)) = 1
390             'for speed changes
391         num.slowed = num.slowed + 1
392         numh.slowed = numh.slowed + 1
393     always
394 always
395     'fighter behind heavy
396     if (dist.btw(i) lt 2. or
        speed.set(s.radar(airplane)) = 1)
        and
397         speed.set2(s.radar(airplane)) = 0
398         and
399         type(s.radar(airplane)) = 0
400         and
401         type(airplane) = 1
402         and
403         (cal.as(s.radar(airplane)) gt 174. or
404             speed.set(s.radar(airplane)) = 1)
405         speed.set(s.radar(airplane)) = 1 'drops
406             kcas to 165
407         cal.as(s.radar(airplane)) =
            cal.as(s.radar(airplane)) - 3
408         if cal.as(s.radar(airplane)) lt 165
409             cal.as(s.radar(airplane)) = 165
410             speed.set2(s.radar(airplane)) = 1
411                 'for speed changes
412                 num.slowed = num.slowed + 1
413     always
414 always
415     'heavy behind heavy
416     if (dist.btw(i) lt 1.8 or
        speed.set(s.radar(airplane)) = 1)
        and
417         speed.set2(s.radar(airplane)) = 0
418         and
419         type(s.radar(airplane)) = 1
420         and
421         type(airplane) = 1
422         and
423         (cal.as(s.radar(airplane)) gt 174. or
424             speed.set(s.radar(airplane)) = 1)
425         speed.set(s.radar(airplane)) = 1 'drops
426             kcas to 165
427         cal.as(s.radar(airplane)) =
            cal.as(s.radar(airplane)) - 3
428         if cal.as(s.radar(airplane)) lt 165
429             cal.as(s.radar(airplane)) = 165
430             speed.set2(s.radar(airplane)) = 1
431                 'for speed changes
432                 num.slowed = num.slowed + 1
433                 numh.slowed = numh.slowed + 1

```

```

433             always
434         always
435     always
436     loop
437     i = 0
438     always
439
440     wait .0001 seconds
441     kcas = cal.as(ftr)
442
443     if r le 10.43515
444         count = 0
445     always
446
447     if r le 10.73515
448         if (y - e1) le 0
449             dive = 0
450         else
451             dive = 2.6
452         always
453     always
454
455     if r le 4.43515
456         if heavy = 0
457             activate a ftr1 giving r now
458             wait 1 seconds
459         else
460             activate a heavy2 giving r now
461             wait 1 seconds
462         always
463     else
464         wait 1 seconds
465     always
466
467     if r le 4.73515
468         if heavy = 0 and kcas gt 165
469             and
470             set.speed2 = 0
471             and
472             speed.set(ftr) = 0
473         kcas = kcas - 1.8
474         if kcas lt 165
475             kcas = 165
476             set.speed2 = 1
477         always
478     always    line 479 deleted; blank line
479     if heavy = 1 and kcas gt 140 and set.speed3 = 0
480         kcas = kcas - 1.8
481         if kcas lt 140
482             kcas = 140
483             set.speed3 = 1
484         always
485     always
486

```

```

487
488     if r gt 1.93515 and heavy = 0
489         and
490         (set.speed2 = 1 or speed.set(ftr) = 1)
491         if ((kcas + change) gt 175) or ((kcas + change)
                                lt 160)
492             kcas = kcas - change
493         else
494             kcas = kcas + change
495         always
496     always
497
498     if r gt 1.93515 and heavy = 1 and set.speed3 = 1
499         if ((kcas + change) gt 150) or ((kcas + change)
                                lt 135)
500             kcas = kcas - change
501         else
502             kcas = kcas + change
503         always
504     always
505 always
506
507     if r le 1.93515 and kcas ge 30 and heavy = 0
508         kcas = kcas - 2.55
509     always
510     if kcas lt 30
511         kcas = 30
512     always
513
514     if r lt 1.93515 and out = 0
515         call cycle
516         remove the first ftr from the radar
517         out = 1
518     always
519 loop
520 end

```

```
1 process ftr.gen
2
3 define heavy, p as integer variables
4
5 while p lt 1
6   do
7     heavy = 0
8     activate a ftr giving heavy now
9     wait 10 seconds
10    p = p + 1
11  loop
12
13 end
```

```
1 process ftr1 given r1
2
3 define r1 as a double variable
4
5 show ftr1 with "ftr1"
6 let r1 = (r1 * 15/2) + .45635
7 let location.a(ftr1) = location.f(23.95, r1)
8 wait 1 seconds
9
10 end
```

```

1 process ftr2 given kcas2, x2, y2, r, error2, phi2
2
3 'process drags the wingman
4
5 define x2, y2, r as double variables
6 define kcas2, ktas2, dive2, vvi2, error2, error2.del,
   phi2, phi2.del,
7     change, theta2, ground.speed2, wind as real
   variables
8 define out, set.speed, set.speed2, in.set as integer
   variables
9
10 define airplane as a pointer variable
11
12 rad(ftr2) = r
13 cal.as(ftr2) = kcas2
14 wait .0001 seconds
15 wait .0001 seconds
16 kcas2 = cal.as(ftr2)
17 wait 1 seconds
18 type(ftr2) = 0
19 wingman(ftr2) = 1
20
21 while r gt .5
22     do
23         if set.speed = 0
24             if kcas2 gt 180
25                 kcas2 = kcas2 - 4
26             if kcas2 lt 180
27                 kcas2 = 180
28             set.speed = 1
29         always
30     always
31 always
32
33 if y2 le 5000 and y2 gt 0
34     ktas2 = (kcas2 * 321.4/300) - (.00428 * kcas2/300 *
   (5000 - y2))
35 always
36
37 if r gt 1.93515 and y2 gt 4000
38     wind = 60
39 else
40     wind = 20
41 always
42
43 theta2 = dive2/360 * 2 *pi.c
44 ground.speed2 = (ktas2-wind)*cos.f(theta2)/3600 'in
   nautical miles/sec
45 vvi2 = ktas2 * sin.f(theta2) * (6076/3600) 'in
   ft/sec
46

```

```

47   if r gt 15 and r lt 20 and error2 gt .8
48     phi2 = -4
49   always
50   if r gt 15 and r lt 20 and error2 lt -.8
51     phi2 = 4
52   always
53   if r gt 10 and r lt 15 and error2 gt .5
54     phi2 = -3
55   always
56   if r gt 10 and r lt 15 and error2 lt -.5
57     phi2 = 3
58   always
59   if r gt 5 and r lt 10 and error2 gt .25
60     phi2 = -2
61   always
62   if r gt 5 and r lt 10 and error2 lt -.25
63     phi2 = 2
64   always
65   if r gt 4
66     phi2.del = uniform.f(-.3, .3, 6)
67   else
68     phi2.del = 0
69     phi2 = 0
70     error2 = 0
71   always
72
73   phi2 = phi2 + phi2.del
74   error2.del = ground.speed2 * sin.f(phi2*2*pi.c/360)
75   error2 = error2 + error2.del
76   let x2 = x2 - ground.speed2 * cos.f(phi2*2*pi.c/360)
77   let y2 = y2 - vvi2
78   if x2 le 0
79     let x2 = 0
80   always
81   if (y2 - e1) le 0
82     let y2 = e1
83     dive2 = 0
84   always
85   r = sqrt.f( ((y2 - e1)/6076)**2 + (x2**2) +
               (error2**2) )
86
87   rad(ftr2) = r
88   if r gt 3.93515
89     show ftr2 with "ftr2"
90     let location.a(ftr2) = location.f(37.5 + error2,
91                                     r)
92   else
93     erase ftr2
94   always line 93 deleted; blank line
95   if speed.set2(ftr2) = 1
96     change = uniform.f(-.3, .3, 3)
97   else
98     change = uniform.f(-.7, .7, 3)
99   always

```

```

99
100   if r lt 17.73515 and r gt 4.73515 and set.speed = 1
101     if ((kcas2 + change) gt 187) or ((kcas2 + change)
102       lt 175)
103       kcas2 = kcas2 - change
104     else
105       kcas2 = kcas2 + change
106     always
107   always
108   if r le 10.48515 and in.set = 0
109     file the ftr2 last in radar
110     in.set = 1
111   always
112
113   if r le 10.73515
114     if (y2 - e1) le 0
115       let y2 = e1
116       dive2 = 0
117     else
118       dive2 = 2.6
119     always
120   always
121
122   if r le 4.73515 and kcas2 gt 165
123     and
124     set.speed2 = 0 and speed.set(ftr2) = 0
125     kcas2 = kcas2 - 1.8
126     if kcas2 lt 165
127       kcas2 = 165
128     set.speed2 = 1
129   always
130   always
131
132   if r lt 4.73515 and r gt 1.93515
133     and
134     (set.speed2 = 1 or speed.set(ftr2) = 1)
135     if ((kcas2 + change) gt 175) or ((kcas2 + change)
136       lt 160)
137       kcas2 = kcas2 + change
138     else
139       kcas2 = kcas2 - change
140     always
141   always
142   cal.as(ftr2) = kcas2
143   wait .0001 seconds
144
145   if r le 10.48515
146     count = count + 1
147   always
148

```



```

149     if n.radar gt 1 and count = n.radar
150     for each airplane in radar
151     do
152         let i = i + 1
153         if i lt n.radar
154             dist.btw(i) = rad(s.radar(airplane)) -
155                         rad(airplane)
156             if (dist.btw(i) lt 1.55 or
157                 speed.set(s.radar(airplane)) = 1)
158                 and
159                 speed.set2(s.radar(airplane)) = 0
160                 and
161                 type(s.radar(airplane)) = 0
162                 and
163                 type(airplane) = 0
164                 and
165                 (cal.as(s.radar(airplane)) gt 174. or
166                 speed.set(s.radar(airplane)) = 1)
167                 speed.set(s.radar(airplane)) = 1
168                 cal.as(s.radar(airplane)) =
169                     cal.as(s.radar(airplane)) - 3
170                 if (cal.as(s.radar(airplane)) lt 165)
171                     cal.as(s.radar(airplane)) = 165
172                     speed.set2(s.radar(airplane)) = 1
173                     num.slowed = num.slowed + 1
174                     if wingman(s.radar(airplane)) = 1
175                         numw.slowed = numw.slowed + 1
176                     always
177                 always
178                 always
179                 if (dist.btw(i) lt 2. or
180                     speed.set(s.radar(airplane)) = 1)
181                     and
182                     speed.set2(s.radar(airplane)) = 0
183                     and
184                     type(s.radar(airplane)) = 1
185                     and
186                     type(airplane) = 0
187                     and
188                     (cal.as(s.radar(airplane)) gt 174. or
189                     speed.set(s.radar(airplane)) = 1)
190                     speed.set(s.radar(airplane)) = 1
191                     cal.as(s.radar(airplane)) =
192                         cal.as(s.radar(airplane)) - 3
193                     if cal.as(s.radar(airplane)) lt 165
194                         cal.as(s.radar(airplane)) = 165
195                         speed.set2(s.radar(airplane)) = 1
196                         num.slowed = num.slowed + 1
197                         numh.slowed = numh.slowed + 1
198                     always
199                 always

```

```

197         if (dist.btw(i) lt 2. or
198             speed.set(s.radar(airplane)) = 1)
199             and
200             speed.set2(s.radar(airplane)) = 0
201             and
202             type(s.radar(airplane)) = 0
203             and
204             type(airplane) = 1
205             and
206             (cal.as(s.radar(airplane)) gt 174. or
207             speed.set(s.radar(airplane)) = 1)
208             speed.set(s.radar(airplane)) = 1
209             cal.as(s.radar(airplane)) =
210                 cal.as(s.radar(airplane)) - 3
211             if cal.as(s.radar(airplane)) lt 165
212                 cal.as(s.radar(airplane)) = 165
213                 speed.set2(s.radar(airplane)) = 1
214                 num.slowed = num.slowed + 1
215             always
216         always
217         if (dist.btw(i) lt 1.8 or
218             speed.set(s.radar(airplane)) = 1)
219             and
220             speed.set2(s.radar(airplane)) = 0
221             and
222             type(s.radar(airplane)) = 1
223             and
224             type(airplane) = 1
225             and
226             (cal.as(s.radar(airplane)) gt 174. or
227             speed.set(s.radar(airplane)) = 1)
228             speed.set(s.radar(airplane)) = 1
229             cal.as(s.radar(airplane)) =
230                 cal.as(s.radar(airplane)) - 3
231             if cal.as(s.radar(airplane)) lt 165
232                 cal.as(s.radar(airplane)) = 165
233                 speed.set2(s.radar(airplane)) = 1
234                 num.slowed = num.slowed + 1
235                 numh.slowed = numh.slowed + 1
236             always
237         always
238         always
239         loop
240         i = 0
241         always
242         wait .0001 seconds
243         kcas2 = cal.as(ftr2)
244         if r le 10.48515
245             count = 0
246         always

```

```

246
247     if r le 4.43515
248         activate a ftr3 giving r now
249         wait 1 seconds
250     else
251         wait 1 seconds
252     always
253
254     if r le 1.93515 and kcas2 gt 30
255         kcas2 = kcas2 - 2.55
256         if kcas2 lt 30
257             kcas2 = 30
258         always
259     always
260
261     if r lt 1.93515 and out = 0
262         call cycle
263         remove the first ftr2 from the radar
264         out = 1
265     always
266 loop
267
268 end

```

```
1 process ftr3 given r3
2
3 show ftr3 with "ftr3"
4
5 define r3 as a double variable
6 let r3 = (r3 * 15/2) + .45635
7 let location.a(ftr3) = location.f(23.95, r3)
8 wait 1 seconds
9
10 end
```

```
1 process heavy.gen
2
3 define heavy as an integer variable
4
5 while q lt 1
6   do
7     heavy = 1
8     activate a ftr giving heavy now
9     q = q + 1
10    wait 50 seconds
11  loop
12
13 end
```

```
1 process heavy2 given r
2
3 show heavy2 with "heavy2"
4 define r as a double variable
5
6 let r = (r * 15/2) + .45635
7 let location.a(heavy2) = location.f(23.95, r)
8 wait 1 seconds
9 erase heavy2
10
11 end
```

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Vita

Major John S. Stieven was born on 13 July 1958 in St. Louis, Missouri to Sesto and Teresa Stieven, the third of four children. He graduated from St. Louis University High School in 1976 and attended Parks College, graduating with a Bachelor of Science in Aeronautical Engineering in July 1979. He came onto active duty in December 1979 at Mather AFB, California, and graduated from Undergraduate Navigator Training. He was assigned to the F-4E at Seymour Johnson AFB where he was selected for Pilot Training. He graduated first in his class at Sheppard AFB in 1985 and was reassigned to the F-4E at Seymour Johnson AFB. He then was chosen for the 13th Air Force Staff at Clark AB, Republic of the Philippines, in 1988. He was transferred to the 3rd Tactical Fighter Wing where he was the Director of Operation's Executive Officer for two years. He was chosen to help run cleanup operations after the century's largest volcano, Mt. Pinatubo, erupted in May 1991. He entered the School of Engineering, Air Force Institute of Technology, in August 1991

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13. ABSTRACT (Maximum 200 words) <p>The purpose of this study was to analyze the proposed addition of heavy KC-135 tanker aircraft to the United States Air Force Aircraft Surge Launch and Recovery (ASLAR) instrument approach system. The Air Force Communications Command, which oversees ASLAR operations, will use these results to determine if KC-135 aircraft should be permitted to fly ASLAR approaches.</p> <p>A SIMSCRIPT II.5 animated simulation model was developed to simulate the Runway 26 approach at Seymour Johnson Air Force Base under a variety of wind conditions. This model was expanded to show the feasibility of KC-135s flying ASLAR approaches and to determine proper controller procedures to prevent the minimum enroute separation between aircraft from being violated. The study noted a concern with reduced separation between a KC-135 and a trailing fighter due to wake turbulence and recommended a cautious, incremental approach be applied to reducing the enroute distance.</p>				
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